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NEW SCOUT CRUISERS *CHESTER*, *BIRMINGHAM*, *SALEM*.

By W. F. SICARD.

By an Act of Congress, approved April 27, 1904, provision was made for the construction of—

One first-class battleship, of not more than 16,000 tons trial displacement.

Two first-class armored cruisers, of not more than 14,500 tons trial displacement.

Three scout cruisers, of not more than 3,750 tons trial displacement.

All the above vessels to be built under the provisions of the Act of August 3, 1896, as to material for hulls, engines, boilers, machinery, etc., except that no premiums are offered and that all parts shall be of domestic manufacture. The Act states that not more than two of these vessels shall be built by one contracting party, and further authority was given the Secretary of the Navy that he "may build any or all of the vessels herein authorized in such navy yards as he may designate, and shall build any of the vessels herein authorized in such navy yards as he may designate, should it reasonably

appear that the persons, firms or corporations, or the agents thereof, bidding for the construction of any of said vessels have entered into any combination, agreement or understanding the effect, object or purpose of which is to deprive the Government of fair, open and unrestricted competition in letting contracts for the construction of any of said vessels."

As has been previously noted in the JOURNAL, the contracts for the battleship and the armored cruisers have already been awarded, that for the battleship, No. 25, *New Hampshire*, to the New York Shipbuilding Co., Camden, N. J., those for the armored cruisers, *Nos. 12 and 13*, *North Carolina* and *Montana*, to the Newport News Co.

Regarding the scout cruisers, the Act reads:

"Three scout cruisers of not more than three thousand seven hundred and fifty tons trial displacement, carrying the most powerful ordnance of vessels of their class; to have the highest speed compatible with good cruising qualities and great radius of action, and to cost, exclusive of armament, not exceeding one million eight hundred thousand each."

The interval between the passage of this Act in 1904 and issuing the circulars for the scouts in February, 1905, was employed in perfecting the design of these vessels.

The type of vessel to which the scout cruisers belong is a new one, just being introduced, and the three described here are the first to be built for our Navy. The British are just completing their first vessels of this class, six in number, and are now running off their trials.

Before proceeding with a detailed description of the *Chester* and class, it may be of interest to compare them with the new British scouts. The general particulars are given on the opposite page.

While the table shows that on paper the speed of the American boat is one knot less, it is well to note that her greater size and freeboard should enable her to sustain an average sea speed, in all kinds of weather, at least equal to the British boats, while the difference in the coal capacity gives a vastly superior radius of action.

	British scouts.			U. S. scouts.
	Adventure. Attentive.	*Foresight. Forward.*	*Pathfinder Patrol.*	*Chester* Class.
Displacement, tons	2,910	2,545	2,500	3,750
Length, feet	374	360	360	423
Beam, feet	38¼	38¼	38	46.6
Draught, feet	13¾	13	13¼	16¾
I.H.P.	16,000	16,000	17,000	16,000
Armament	10 12-pdrs.	10 12-pdrs.	10 12-pdrs.	12 3-inch.
Torpedo tubes	2	2	2	2
Speed, knots per hour	25	25	25	24
Coal, tons	470	380	380	1,250

The scout cruiser is a very interesting class of vessel, and presents many points of great professional interest to the marine engineer. Being vessels of relatively small displacement and high speed, great power is required to drive them as they approach their limit of speed. The problem, on the other hand, is different from that presented by the "Destroyer" type, in that the scout must be able to sustain high speed indefinitely, requiring more reliable and therefore heavier machinery. The difficulty of installing this powerful machinery on the limited weight available requires that it be very carefully designed and every superfluous pound omitted. The fact that this appropriation provides for three vessels of this high-speed class, affords an ideal opportunity for comparison of different systems of propulsion applied to similar vessels of the same size and type, and installations of reciprocating engines and turbines of different design would give most valuable data and experience to apply in the design of other vessels.

The plans and the specifications issued by the Department called for reciprocating engines; the circular, however, in advertising for these vessels to be built under contract invited proposals for their construction under two classes, as follows:

Class 1.—For the construction of the hull and machinery, including engines, boilers and their appurtenances, and for equipment, complete in all respects, in accordance with the plans and specifications provided by the Secretary of the Navy, and for the installation of ordnance and ordnance outfit.

Class 2.—For the construction of the hull, and for equipment, complete in all respects, and for the installation of ordnance and ordnance outfit, in general accordance with the plans and specifications provided by the Secretary of the Navy, but on the bidder's design of machinery, preference being given, other things being equal, to a turbine installation.

The specifications submitted by the bidders under Class 2 must cover fully the ground covered by the Department's specifications, and must be so drawn as to cover the detailed requirements of the different Bureaus of the Department. * * * Any design of machinery submitted must be in such detail and accompanied by such plans, specifications and calculations as to enable the Department to readily determine its value, and to ascertain whether it fulfills the general requirements herein mentioned; the calculations to include complete calculations of weights and centers of gravity, and also such calculations as will demonstrate the satisfactory strength of the whole.

The maximum time allowed for completion will be limited by the Department to thirty-two months if reciprocating engines are adopted, and thirty-six months if turbines are adopted, and no bids will be considered which propose to exceed those limits. Failure to complete the vessel within the time specified in the contract will involve penalties as follows, viz: $100 a day for the first month succeeding the expiration of the period fixed by the contract, and $200 a day thereafter until the vessel is completed and delivered as prescribed by the contract.

The requirements as to trials are as follows:

I. A progressive trial over a measured-mile course, for standardizing the screws, extending from maximum speed down to about 12 knots; about sixteen runs to be made over the course in order to cover the range of speed desired, these runs to be made in a depth of water of not less than 30 fathoms.

II. A full-speed trial of four hours' duration in the open sea in deep water, the speed developed by the vessel to be not less than 24 knots an hour, as determined by the revolutions of the main engines. The air pressure not to exceed an average

of five inches of water, and the steam pressure in the high-pressure valve chests not to exceed 250 pounds. No live steam shall be admitted to the receivers. The full-speed trial displacement not to exceed 3,750 tons.

III. An endurance and coal-consumption trial of twenty-four hours in the open sea, in water not less than 30 fathoms in depth, at a speed as nearly uniform as possible, which shall average for the twenty-four hours not less than 22½ knots, as determined from the corresponding revolutions taken from the standardization trial results. Record shall be made of the coal consumed. All necessary auxiliaries shall be in operation. Samples of the coal used shall be taken during this trial for purposes of analysis and determination of heating value.

IV. An endurance and coal-consumption trial of twenty-four hours in the open sea at an average uniform speed of 12 knots, as nearly as possible. This trial shall be made as nearly as possible under service cruising conditions and the coal consumption for all purposes carefully determined.

There are the usual penalties for over time, over weight and under speed, with provision for acceptance at a reduced price, or for non-acceptance.

The bids were opened at the Navy Department, at noon, April 15, 1905, six firms bidding. No firm can, under the Act, be allowed more than two vessels. The bids were as follows:

SCOUT CRUISER BIDS.

MARYLAND STEEL COMPANY.

One ship, Department's plans, 32 months	$1,875,000
*One ship, turbines, 36 months	1,875,000

NEW YORK SHIPBUILDING COMPANY.

One ship, Department's plans, 32 months	1,824,000
One ship, turbines, 36 months, two shafts	1,830,000
One ship, turbines, 36 months, 3 shafts	1,866,000

Westinghouse turbines proposed.

*No performance guaranteed.

WILLIAM CRAMP & SONS.

One ship, Department's plans, 32 months..... 1,793,000
Two ships, Department's plans, 31 and 32 months.....each 1,750,000
One ship, turbines, 36 months, 3 or 4 shafts..... 1,885,000
Two ships, turbines, 35 and 36 months, 3 or 4 shafts.....each 1,825,000
Parsons turbines proposed.

BATH IRON WORKS.

One ship, Department's plans, 32 months..... 1,774,000
Two ships, Department's plans, 32 months.....each 1,729,000
One ship, Department's plans, 32 months, 12 boilers..... 1,767,000
Two ships, Department's plans, 32 months, 12 boilers.....each 1,738,000
* One ship, turbines, 36 months, 12 boilers, 3 shafts, cruising turbines..... 1,671,000
* Two ships, turbines, 36 months, 12 boilers, 3 shafts, cruising turbines.....each 1,623,000
* One ship, turbines, 36 months, 12 boilers, 3 shafts, no cruising turbines..... 1,639,000
* Two ships, turbines, 36 months, 12 boilers, 3 shafts, no cruising turbines.....each 1,595,000
One ship, turbines, 36 months, 8 boilers, 3 shafts, cruising turbines..... 1,654,000
Two ships, turbines, 36 months, 8 boilers, 3 shafts, cruising turbines.....each 1,606,000
One ship, turbines, 36 months, 8 boilers, 3 shafts, no cruising turbines..... 1,611,000
Two ships, turbines, 36 months, 8 boilers, 3 shafts, no cruising turbines.....each 1,573,000
* One ship, turbines, 36 months, 12 boilers, 4 shafts, cruising turbines..... 1,688,000
* Two ships, turbines, 36 months, 12 boilers, 4 shafts, cruising turbines.....each 1,640,000
* One ship, turbines, 36 months, 12 boilers, 4 shafts, no cruising turbines..... 1,658,000
* Two ships, turbines, 36 months, 12 boilers, 4 shafts, no cruising turbines.....each 1,610,000
One ship, turbines, 36 months, 8 boilers, 4 shafts, cruising turbines..... 1,671,000
Two ships, turbines, 36 months, 8 boilers, 4 shafts, cruising turbines.....each 1,622,000
One ship, turbines, 36 months, 8 boilers, 4 shafts, no cruising turbines..... 1,640,000
Two ships, turbines, 36 months, 8 boilers, 4 shafts, no cruising turbines.....each 1,592,000
Parson's turbines proposed. Normand boilers.
Bids marked * guarantee 24½ knots.

UNION IRON WORKS.

One ship, Department's plans, 32 months	1,689,000
Two ships, Department's plans, 32 months	each 1,666,000

FORE RIVER SHIPBUILDING COMPANY.

One ship, Department's plans, 30 months	1,629,000
Two ships, Department's plans, 30 and 31 months	each 1,557,000
One ship, turbines, 34 months	1,540,000
Two ships, turbines, 34 and 35 months	each 1,468,000
One ship, reciprocating engines, 30 months	1,598,000
Two ships, reciprocating engines, 30 and 31 months	each 1,524,000
One ship, turbines, 34 months	1,572,000
Two ships, turbines, 34 and 35 months	each 1,500,000
Two ships, { One, turbines / One, reciprocating engines, 34 and 30 months, each.. }	1,525,000
Two ships, { One, turbines / One, Department's plan, 34 and 30 months, each... }	1,556,000

Curtis turbines proposed. Fore River boilers.

Contracts were awarded by the Department as follows:

Scout cruiser *No. 1*, *Chester*, Parsons turbine, to the Bath Iron Works, Bath, Me. Scout cruiser *No. 2*, *Birmingham*, Department's design with reciprocating engines, and *No. 3*, *Salem*, Curtis turbines, to the Fore River Shipbuilding Company, Quincy, Mass.

GENERAL DESCRIPTION.

The vessels and machinery are to be subject to the usual strict Government specifications and rigid inspection.

The general dimensions and features are as follows:

Length between perpendiculars, feet	420
Breadth, molded, feet and inches	46– 8
Displacement on speed-trial, not more than, tons	3,750
Mean draught to bottom of keel at trial displacement, not to exceed feet and inches	16– 9½
Total coal-bunker capacity, about, tons	1,250
Coal carried on speed trial, tons	475
Feed water carried on speed trial, tons	50

The hull is to be of steel throughout.

The armament will consist of twelve 3-inch rapid-fire guns, two submerged torpedo tubes, and a full allowance of rifles, revolvers and cutlasses for the crew.

The magazines are at each end of the ship, of equal capacity, with ventilated spaces next to the bulkhead, where same separates them from heated compartments.

The ammunition hoists, electrically driven, and capable of supplying each 12 pieces per minute, deliver their ammunition as near as possible to the place where it is required.

The sides of the vessel will be covered throughout the limits of the machinery space with 2-inch nickel-steel, to an average height of about 8 feet above and 3 feet below the water line.

PROPELLING MACHINERY.

The vessel will be propelled by twin screws, turning outboard when going ahead, each screw being driven, through its shafting, by a vertical, inverted, direct-acting, triple-expansion, four-cylinder engine. Each engine will be in a separate watertight compartment, these compartments being arranged, as on a destroyer, one forward of the other. The main engine cylinders are arranged as follows, beginning forward: Low-pressure, high-pressure, intermediate-pressure and low-pressure. The four cranks are at 90 degrees, the forward low-pressure and high-pressure cranks being opposite, as are the intermediate and after low-pressure, the sequence being high-pressure, intermediate-pressure, forward low-pressure and after low-pressure.

The general particulars of engines will be as follows:

Diameter of high-pressure cylinder, inches	28¼
intermediate-pressure cylinder, inches	45
forward low-pressure cylinder, inches	62
after low-pressure cylinder, inches	62
Stroke of all pistons, inches	36
Indicated horsepower of both main engines	16,000
Revolutions	200
Steam pressure, at high-pressure receiver, pounds	250

The engines are of the usual Bureau design, with open framing. The forward low-pressure and high-pressure cylinders are bolted together, as are the intermediate and the after low-pressure cylinders. There are fore-and-aft tie rods between cylinders, and pads for athwartship tie rods in case they are

found necessary. There is one set of valve gear for each cylinder, interchangeable as far as possible, and all valves are of the piston type with Stephenson link motion. The engines are provided with all the necessary auxiliaries and accessories, in accordance with the latest practice of the Bureau of Steam Engineering.

The main air pumps are independent and double acting, the circulating pumps are centrifugal and each capable of discharging 11,000 gallons of water per minute from the bilge. Steam turbines may be used for the circulating pumps, provided the guaranteed steam consumption does not exceed 50 pounds of steam per indicated horsepower per hour.

Each engine has an independent, steel shell, cylindrical condenser of about 8,000 square feet of cooling surface. In addition to this there is an auxiliary condenser of 600 square feet surface, and a dynamo condenser of 200 square feet surface.

There will be twelve water-tube boilers of the "Express" type, in six water-tight compartments. The steaming capacity will be such that all steam machinery on board can be run at full power with an average air pressure in the ashpits of not more than 5 inches of water. The total grate surface will be at least 693 square feet, and the total heating surface at least 37,080 square feet. The working pressure will be 275 pounds per square inch.

All pressure parts of boilers will be constructed entirely of open-hearth steel plate and seamless steel tubes. No malleable or cast iron or cast steel will be used under pressure. There will be no screw joints in contact with the fire.

The provision for removing and renewing tubes, the method of baffling to provide for the proper circulation of the gases, and the facilities for cleaning soot off tubes and baffles will be fully shown on plans submitted by contractors.

The boiler tubes will be "cold-drawn seamless steel tubes," of the following thicknesses:

1 inch diameter, outside, ...	No. 12, B.W.G.
1⅛ inches diameter, outside, . . .	No. 11, B.W.G.
1¼ inches diameter, outside, . . .	No. 11, B.W.G.

The steam and water drums will be of the following dimensions:

Steam drums, not less than 40 inches, inside diameter.

Water drums, not less than 18 inches, inside diameter.

All rivets will be in accordance with the Navy standard, and where possible hydraulic riveting will be used; where hydraulic riveting cannot be used, the rivet holes will be coned and conical rivets used. All rivets will be driven with at least 60 tons pressure and held until cool. No snap riveting will be used on any part of the boilers except the casing. Seams will be calked on both sides in an approved manner. If welded drums are used, the weld must be plainly marked, and the tube holes must not be drilled in weld.

Tube holes should be smooth, true and absolutely free from scoring or grooving. The edges of all tube holes in boiler drums must be sufficiently rounded to prevent cutting the tubes when expanded.

The closed fireroom system of forced draft is used, air being supplied by six blowers, located on the deck above the machinery space.

There are four smoke pipes, about 72 feet in height above the base line.

The following auxiliary steam machinery of approved make and design, in addition to that pertaining to the main engines and dependencies, is to be supplied by the contractor and installed complete with all piping and fittings: Steering engine, windlass engine, ash-hoist engines for each fireroom, forced-draft blowers, evaporating plant, to consist of not less than four units, having a total capacity of 16,000 gallons of fresh water per day; a distilling apparatus capable of condensing at least 16,000 gallons of water per day. The workshop tools and the ice machines will be operated by steam engines or electric motors. There will be a refrigerating plant with a cooling effect of 2 tons of ice per 24 hours.

The vessel is to be heated with steam throughout, and the usual steam-heating system will be provided and installed by the contractor.

The weight of all machinery and tools, stores and spare parts will be about 798 tons. This weight must include all articles, except stores supplied by the Government, irrespective of name or use, coming under the cognizance of the Bureau of Steam Engineering, including water in boilers, condensers, evaporators, tanks, piping, etc., but excluding the reserve feed water in the double bottom or tanks.

The following machine tools, of approved make and design, will be furnished and installed by the contractor in the general workshop:

One screw-cutting back-geared extension gap lathe, to swing 16 inches over the upper ways and 32 inches over the lower ways, and to take between centers 7 feet when extended.

One 12-inch screw-cutting back-geared tool-room lathe, to take not less than 4 feet between centers.

One column tool-room shaper of about 15 inches stroke and not less than 15 inches traverse.

One upright drill press, to drill up to 1½ inches in steel, 14 inches from edge of work, with at least 14 inches traverse of spindle.

One universal milling machine, with not more than 18-inch table feed, 4½-inch traverse and 13-inch vertical feed.

One combined hand punch and shears, with 6-inch shear blades, to cut ¾-inch round iron, shear ⅝-inch steel plate, and punch ⅝-inch holes in ⅝-inch mild steel plates 4 inches from edge.

One emery grinder on column, with two carborundum wheels 12 inches in diameter and 2-inch face.

Three bench vises.

One blacksmith forge with tools and fixtures will be supplied and installed in the blacksmith shop.

Electric Plant.—The vessel will be lighted throughout by electricity. The electric plant will consist of three 32-kilowatt steam-driven generating sets, all to be of 125 volts pressure at the terminals, 600 electric fixtures, complete, with necessary incandescent lamps and outlets; two arc lamps for each engine room, one arc lamp for each firing position in boiler rooms,

PUMPS AND CONNECTIONS.

No.	Pumps.	Size (inches).	Kind.	Suction pipes from—		Discharge pipes to—		Location.
				Ins.		*Ins.*		
2	Main air....	2 12-inch, 2 22-inch, by 18.	Double, vertical, bucket, double-acting.	11	Condenser.	9½	Main feed tanks.	One in each engine room.
2	Main circulating.	Centrifugal.....	Vertical compound, or turbine.	16½ 6½	Sea. Main drain.	16½ 16½	Condenser. Overboard.	One in each engine room.
2	Main feed.	15 by 10 by 15...	Vertical piston, double-acting, single.	6 6	Feed-tank connecting pipe. Channel ways.	5 5	Main feed discharge main. Main feed tanks.	One in each engine room.
3	Fireroom feed.	9 by 6 by 12.....	Vertical piston, double-acting, single.	2½ 3½ 3½ 3½	Bottom blows in same compartment. *C. and R. pipes from ship's sides. Feed suction pipe. *Reserve feed-water tanks.	3 3 3 2½ 2½	Auxiliary feed. *Main feed tanks. *Reserve feed-water tanks. Overboard in same compartment. Fire extinguisher.	One in each boiler room.
3	Fireroom fire and bilge.	12 by 8 by 12....	Vertical piston, double-acting, single.	4½ 4½ 4½ 1½	Fireroom floors in same compartment. Sea. C. and R. drainage manifolds. Hose connection.	4 4 4 2½	Fire main. Overboard in same compartment. Ash ejector. Hose connection. Fire extinguisher.	One in each boiler room.
2	Fire and bilge.	10 by 8½ by 12...	Vertical piston, double-acting, single.	4½ 4½ 4½	Sea. Engine-room drainage. C. and R. drainage manifolds.	4 4 2½	Fire main. Overboard. Hose connection.	One in each engine room.

Connections marked (*) are on one pump only.

1	Reserve feed	3½ by 4 by 4....	Vertical piston,	3	Reserve feed-water	2½	Feed tank connect-	Forward engine

1	Reserve feed water.	3½ by 4 by 4.....	Vertical piston, double-acting, single.	3	Reserve feed-water tanks.	2½	Feed tank connecting pipe.	Forward engine room.
2	Shaft bilge.	Capacity of each about 300 cubic in. per stroke.	Plunger, single acting.	4	Engine-room bilges.	4	Overboard.	One in each engine room.
2	Distiller circulating.	10 by 10 by 12, or centrifugal.	Horizontal piston, double-acting, single, or turbine.	.....	Sea.	.....	Distillers. Sanitary system. Fire main.	Where directed.
1	Auxiliary air and circulating.	6 by 10 by 10 by 12.	Combined.....	5 5½	Auxiliary condenser. Sea.	3½ 5½	Main feed tanks. Auxil'y condenser.	In forward engine room.
1	Dynamo air and circulating.	6 by 8 by 8 by 12	Combined.....	4 4	Dynamo condenser. Sea.	3 4	Main feed tanks. Dynamo condenser.	In dynamo room.
1	Evaporator feed.	4½ by 5 by 6.....	Light service.....	.....	Sea. Distiller circulating water discharge.	.....	Evaporators.	Where directed.
1	Distiller fresh water.	4½ by 5 by 6.....	Vertical piston, light service.	.....	Bottom of distillers.	....	Fresh water tanks. Main feed tanks. Reserve feed-water tanks.	Where directed.
2	Engine-room oil.	2 by 1½ by 1¾....	Piston, with hand attachment.	.....	Oil-storage tanks.	.....	Distributing tank, with overflow pipe from tank to pump suction.	One in each engine room.
.....	Other pumps as may be required.		As approved.....	.....	As may be required.	.....	As may be required.	As approved.

twelve arc lamps for coaling operations, capacity about four ampères; one electric log; two 60-inch searchlights, complete; two double truck lights, one electric night signal set with typewriter form of keyboard; two diving lamps and eight 150-candlepower incandescent lamps; six portable electric ventilating sets, ¼-horsepower; thirty $\frac{1}{12}$-horsepower bracket fans; six ⅙-horsepower bracket fans; one electric whistle operator with automatic and at-will switch; eleven signal lanterns; a set of ship's running-light fixtures and fittings for wireless telegraph outfit; a complete system of interior communication with two dynamotors, batteries and switches for current supply, lights and outlets for interior communication instruments; necessary switchboards and distribution boards for the efficient operation and control of the electric plant, together with the necessary wire supplies, wiring appliances, wiring accessories and instruments for the above and for all other electric auxiliaries and appliances installed; also conduit tubes and fittings, fixtures, lamps, tools, spare parts and stores necessary for the proper manipulation, test, maintenance and repair of the plant.

There will be fitted all the usual means of interior communication, such as telephones, voice pipes, call bells, buzzers, gongs and annunciators, engine and steering telegraphs, revolution and rudder indicators, heeling indicators, automatic fire alarms, warning signals, alarm signals, stoking telegraph, etc.

With the exception of the auxiliaries before mentioned to be operated by steam, all power on board the vessel will be electric, as, for instance, deck winches, ammunition hoists, ventilation blower motors, air compressor motors, etc.

Ventilation.—All main compartments of the ship below the berth deck, except the coal bunkers, will be provided with ventilation, about 30,000 cubic feet of air per minute being required. Special attention will be given to spaces subject to habitually high temperatures, such as engine rooms and dynamo rooms. All blowers for the ventilation system will be electrically operated.

Coaling Arrangements.—The coal bunkers, of a maximum capacity of 1,250 tons, will be arranged so as to provide a rapid and sufficient supply of coal to the fire rooms. For coaling, four electrically-driven winches will be provided, together with all necessary fixed chutes, scuttles, hatches and other openings. Coaling booms fitted to boat davits will be used in coaling.

Anchor Handling.—Complete arrangements will be provided for the convenient handling and stowage of anchors. There will be one billboard and three hawse pipes, two hawse pipes to be so designed that stockless anchors may be stowed in them. There will be three heavy anchors, one of navy type and two stockless, and the usual smaller ones. Anchor windlass with vertical spindle wildcats, anchor davit, securing and tripping gear, controllers, ring bolts, riding bits, cleats, pad eyes and other fittings will be provided as customary in the naval service.

Boats.—The following boats will be carried, adequate provision being made for their convenient stowage and handling, the necessary boat davits, adjustable boat chocks and all necessary fittings being provided for this purpose:

One 28-foot steam cutter.
One 33-foot launch.
Two 30-foot cutters.
Three 28-foot cutters.
One 30-foot whaleboat.
One 30-foot gig.
One 14-foot dinghy.

Complement.—The arrangement of quarters provides ample accommodations for the following complement: A commanding officer, 12 wardroom officers, 5 warrant officers, not less than 310 men. All wire or metal lockers, bag racks, ditty-box racks, hammock hooks and miscellaneous fittings required for the complete berthing and messing of the crew, and staterooms, mess rooms, etc., for the accommodation of the officers will be provided.

Water Systems.—A complete drainage and flooding system

will be provided, consisting of auxiliary drain in engine and boiler rooms, drains for all bilges, double-bottom drainage for all compartments within watertight longitudinals and flooding for all compartments within machinery spaces and for trimming tanks. Sounding tubes will be fitted to all of the above double-bottom compartments and trimming tanks, and air escapes provided for such compartments as are to be flooded. There will also be installed magazine floods and a complete fire system, with about twenty fire plugs; a flushing and salt-water system for ready supply of salt water to all parts of the ship; also a fresh-water system for furnishing fresh water to all spaces required. The total quantity of fresh water carried in ship's tanks will be about 6,000 gallons, and in gravity tanks 1,000 gallons.

Plumbing.—Plumbing fixtures will be in accordance with the latest approved practice for all bathrooms, lavatories, water-closets and other spaces.

Means of handling and navigating the ship-steering appliances and other arrangements will be such as have been found most satisfactory on naval vessels. Steering station, with power steering wheels, will be located on the bridge, in the chart house and in steering-engine room. Hand-steering gear will be provided in the steering-engine room.

There will be a bridge forward. On the bridge and in the chart house will be fitted a steering wheel, engine telegraphs, indicators, voice tubes, telephones, and all fittings for handling the ship. There will be a brass chart house, a wireless telegraph room and searchlight platforms suitably located.

Masts.—There will be metal masts forward and aft, the foremast in wake of the chart house to be of brass; both masts to be fitted with wood topmasts. There will be a signal yard fitted on each mast. Foremast will be arranged for wireless telegraphy.

Wood Decks.—Exposed main deck, forecastle deck, top of wireless telegraph house and bridge will be planked; all planking to be of yellow pine, with teak margins.

Deck Covering and Joiner Work.—Floor coverings of linoleum, tiling or wood gratings will be fitted. The quantity of wood work will be reduced to the minimum, and no wood work will be fire-proofed.

Sheathing.—All spaces in officers' and crews' quarters on gun and main decks, bounded by the outer hull, also sick bay and dispensary, orlop berth deck, also engine-hatch trunks in wake of staterooms, will be sheathed with sheet metal, cork painted. Metal sheathing will also be fitted over the engine rooms and around fireroom hatches on berth deck.

Provision will be made for carrying three months' allowance of provisions and six months' allowance of clothing and small stores, or such portion thereof as may be practicable.

The following compartments and spaces have been provided for and will be fitted out complete as customary in the naval service: Captain's cabins, officers' staterooms, chart house, wardroom country, sick bay, dispensary, berthing spaces, chief petty officers' quarters, commissioned and warrant officers' mess rooms, captain's office, executive officer's office, paymaster's office, engineer's office, prisons, officers' and sick bay lavatories and bathrooms; firemen's and chief petty officers' wash rooms, chief petty officers' water closets, seamen's head, galleys, general mess pantry, pantries, cold-storage rooms, submerged torpedo room, magazines, wireless-telegraph room, galley issuing room, commissary store, magazines, armory, machinery spaces and evaporator room, dynamo room, steering compartment, windlass-engine space, ice-machine room, general workshop, storerooms of all descriptions, rooms for sails and awnings, paymaster's issuing rooms, oilskin lockers, lucky bag, drying room, paint and paint-mixing rooms, lamp rooms, oil rooms, cleaning-gear locker, chain lockers, fresh-water tank spaces, coal bunkers, double-bottom compartments, trimming tanks, reserve feed water tanks.

The following is a summary of the weights to be carried:

	Tons.
Armament and two-thirds of ammunition and stores,	120
Total protection, nickel-steel, about	183.20
Steam engineering complete, with water in boilers, condensers, piping, etc., and stores, except those furnished by the Government, etc., ...	798
Engineer's stores supplied by the Government, two-thirds full supply, ...	8
Reserve feed water for steaming purposes, . . .	50
Equipment complete, including anchors, chains, electrical plant, etc., and two-thirds full supply of equipment stores, ...	123.2
Coal, trial supply, ...	475
Outfit, including boats, ladders, furniture and blocks,	35
Miscellaneous stores and fresh water, two-thirds full supply, ...	39.90
Officers, crew and effects, ...	45.70
Provisions, clothing and small stores, ...	40

A DESTROYER IN SERVICE.

ONE YEAR'S PERFORMANCE.

By Lieutenant G. C. Davison, U. S. N., Member.

One of the most valuable features of the Journal is its description of new vessels and accounts of their acceptance trials. But it is a well-known fact that in service trial-trip data is seldom duplicated, owing to various causes, such as increased displacement, foul bottom, deterioration of machinery plant and the element of personnel. It might therefore be interesting and valuable to have trial-trip data supplemented by data collected during actual service. The difference between trial-trip and service performance is probably greater in torpedo craft than in any other class of vessel, for the reason that there is a greater proportionate increase of displacement, and they are more sensitive to any change in the condition of their bottoms.

The *Paul Jones* is the destroyer for which service data is given below. A description of this vessel, and her two sister craft, the *Perry* and *Preble*, with an account of their official trials, is given in Journal No. 3, Vol. XIV. For convenience of reference the following general data is repeated:

Length, feet and inches	250– 7⅞
Beam, extreme, feet and inches	23– 6½
Mean draught, feet and inches	7– 1½
Displacement on trial, tons	474.5
R.P.M., main engines	322.4
Speed, knots per hour	27.4
Slip, per cent	18.2
Total H.P.	6,925
Coal per H.P. hour, pounds	2.34

On July 19, 1902, the *Paul Jones* was delivered to the Government, and was placed in reserve at the Navy Yard, Mare Island, Cal., where she was kept until December 22, 1903.

During this period in reserve she was given occasional short runs, of which there is no data available. It is probable, however, that there was little wear of the machinery during this period, and the deterioration only what is normal on all vessels during the same length of time.

She was, therefore, a comparatively new vessel on going into commission on December 22, 1903. From that date data has been observed and recorded every time she has been under way. Several thousand miles have been covered on short runs of from twenty-five to a hundred or so miles, but all such data is not recorded in the accompanying table, as it would be a useless repetition, and in some cases the coal consumption is not accurate. The longer runs are all given, and in general the observations are quite accurate.

This table really tells the whole story of the performance of the *Paul Jones* for a period of a year and a few months. It would, however, be interesting only to officers with past, present and future duty on a vessel of the same class. But an analysis of the table establishes a few facts of general interest and corrects some apparently false impressions, which, while not general in the service are held by some officers. Some of these erroneous impressions are:

(1) That the economical speed is about 14 knots.

(2) That the law of horsepower varying as the cube of the speed does not apply practically.

(3) That destroyers are weak things which have to be nursed to a certain extent and cannot take care of themselves, and in general are not to be relied upon.

It is not surprising that such false impressions exist, as our destroyers are comparatively recent acquisitions, and inherited much of the reputations of their forerunners, the torpedo boats. While destroyers are actually only big torpedo boats, their bigness lifts them into another class of vessel.

To begin with the analysis of service performance, Fig. 1 gives three horsepower and revolution curves. Curve No. I is from data taken with an absolutely clean bottom. The horsepower and revolutions were taken as accurately as indicators

Run No.	Date.	From	To	Distance, miles.	Speed, knots per hour.	Revolutions per minute.		Revolutions per mile.	Slip, per cent.	Mean displacement.	Months out of dock.*
						Starboard.	Port.				
1	Dec. 30, '03–Jan. 7, '04	San Francisco.....	Acapulco, Mex.....	1,862	10.03	117.46	117.41	702.5	20.3	660	.5
2	Jan. 10–16, '04	Acapulco, Mex.....	Panama, Pan.....	1,570	10.5	117.87	117.87	664	17	625	1
3	Apr. 19–27	Panama, Pan.....	Acapulco, Mex.....	1,550	8.12	105.4	105.3	771.5	28.6	625	4
4	Apr. 29–May 3	Acapulco, Mex.....	Pichilinque, Mex.....	775	8	104	104	783.5	29.5	625	4.5
5	May 7–9	Pichilinque, Mex..	Guaymas and return...	488	12.6	161.7	161.7	756.3	27.1	682	4.5
6	May 9–14	Pichilinque, Mex..	San Diego, Cal.....	916	7.75	102	102	789	29.8	637	5
7	June 3–5	Ventura, Cal.....	San Francisco.....	315	7.06	98	98	832	.....	.....	6
8	June 15–20	San Francisco	Bellingham, Wash.....	854	7.41	99	99	802	.....	.....	6
9	June 23–26	Bellingham	Portland, Ore.....	490	7.55	98–190	98–190	.....	.....	.....	6.5
10	July 11–13	Portland, Ore.....	Bremerton, Wash.....	365	6.8	94.02	94.02	832	33.7	.....	7
11	July 20–23	Bremerton, Wash.	San Francisco.....	845	12.91	162	162	754	26.1	658	7
12	July 27–28	Sausalito, Cal.....	Santa Barbara.....	290	9.4	125	125	798	30.9	.....	7.5
13	Aug. 2–3	Santa Barbara.....	Mare Island.....	310	10.57	134	134	778	29.2	632	8
14	Sept. 17–18	San Francisco.....	Santa Barbara.....	310	10	112.8	113.2	678	18.7	682	0
15	Sept. 18–19	Santa Barbara.....	San Diego.....	170	18	203	204	678.3	18.7	642	0
16	Sept. 22–24	San Diego.....	Magdalena Bay.....	615	13.52	149.9	150.7	667	17.3	610	.5
17	Oct. 5	.....Meeting	mail steamer.....	75	7.7	87.5	88.7	688	20	702	1
18	Oct. 13–15	Magdalena Bay....	San Diego.....	620	16.1	180	185	680	18.9	636	1
19	Oct. 20–22	San Diego.....	Magdalena Bay.....	620	13.8	157.7	158.7	688	20	622	1
20	Oct. 22–24	Magdalena Bay....	San Diego.....	620	14.7	162	163	675	18.7	592	1.5
21	Oct. 26–28	San Diego.....	Magdalena Bay.....	620	13.3	148	148	675	18.7	632	1.5
22	Oct. 28–31	Magdalena Bay....	San Diego.....	620	10.8	122.5	122.5	677	18.7	582	1.5
23	Nov. 7–9	San Diego.....	Magdelena Bay.....	620	12	.....	.....	.....	.....	.....	.....
24	Nov. 16–18	Magdalena Bay....	San Diego.....	650	11	.....	.....	.....	.....	.....	.....
25	Nov. 18–20	San Diego..	Mare Island.....	510	11.17	129 9	129.5	697	20.9	567	2.5
26	Nov. 23–25	Mare Island.....	Port Angeles.....	775	15.2	180	180	684	19.5	670	2.5
27	Dec. 12 1905	Seattle, Wash.....	Bremerton, Wash.....	15	18 4	210	211	680	18.9	545	3
28	Jan. 12	Anacortes, Wash..	Seattle, Wash.....	80	18	206	204	680	18.9	600	4.4
29	Feb. 14	Seattle, Wash.....	Port Townsend.....	40	19	225	225	.....	.....	.....	.....
30	Feb. 24	.....Full power	trial.....	60	25.5*	295	300	706	21.9	582	5.5
31	March 9	Seattle, Wash.....	Port Townsend.....	100	17	200	200	.....	.....	...	...
32	April 5-9	Bremerton, Wash.	Long Beach, Cal.....	1,165	12.5	147	147	706	21.9	660	7.5

CRUISING DATA U. S. TORPEDO BOAT DESTROYER *PAUL JONES*

Mean displacement.	Months out of dock.	Weather.	Bottom.	Indicated H.P.		Receiver pressures, pounds absolute.			
				Main engines.	Collective.	1st Receiver.		2d Receiver	
						S.	P.	S.	P.
660	.5	Good, smooth sea, fair breeze.	Clean.	360	420	15	15	5	5
625	1	Good, smooth sea.	Clean.	400	450	15	15	5	5
625	4	Good, smooth sea.	Foul.	520	580	15	15	7½	7½
625	4.5	Smooth.	Covered with barnacles.	500	550	15	15	7½	7½
682	4.5	Smooth.	Covered with barnacles.	1,379	1,454	45	45	11½	11½
637	5	Moderate on bow.	Covered with barnacles.	.....	.....	20	20	12	12
.....	6	Moderate on bow.	Covered with barnacles.	.....	.....	...	...	...	...
.....	6	Rough on bow.	Covered with barnacles.	.....	.....	...	...	...	...
.....	6.5	Smooth.	Covered with barnacles.	.....	.....	...	...	...	...
.....	7	Rough on bow.	Covered with barnacles.	.....	.....	...	...	...	...
658	7	Smooth.	Very foul.	1,572	1,672	43	43	10	7½
.....	7.5	Rough following sea. (Racing.)	Very foul.	678	728	21	21	7½	10
632	8	Moderate sea ahead.	Very foul.	808	858	26	30	7½	10
682	0	Smooth sea.	Clean.	360	420	26	17	7½	5
642	0	Smooth sea.	Clean.	1,591	1,691	55	45	15	10
610	.5	Moderate following sea.	Clean.	771	800	26	20	7	4
702	1	Half against head sea moderate; wind force 5; half before sea.	Clean.	203	263	15	15	7	5
636	1	Smooth sea.	Clean.	1,350	1,450	34	30	7	6
622	1	Smooth sea.	Clean.	725	825	28	16	7	4
592	1.5	Smooth sea.	Clean.	900	1,000	27	25	8	7
632	1.5	Smooth sea.	Clean.	717	800	23	20	7	7
582	1.5	Moderate head sea.	Clean.	400	500	21	17	7	7
.....	.....	.....	.....	.....	.....	...	...	...	...
.....	... ..	.....	.....	.....	.....	...	...	...	...
567	2.5	Wind force 6 ahead; sea rough.	Moderately foul.	550	620	23	20	7	5
670	2.5	Wind force 7 aft; sea rough.	Moderately foul.	1,400	1,500	40	37	10	12
545	3	Smooth, current not known.	Moderately foul.	2,054	2,200	45	45	15	15
600	4.4	Smooth, current not kdown.	Moderately foul.	2,344	2,500	40	40	11	15
.....	.....	.....	.....	3,050	3,250	...	...	...	...
582	5.5	Smooth. Revolutions per mile determined by measured mile.	Moderately foul.	6,613	6,813	85	86	30	30
...	...	.....	.....	1,971	2,050	...	...	...	...
660	7.5	Various.	Moderately foul.	1,112	1,172	27	28	10	11

* Maximum speed attained, 330 R. P. M. = 27.8 knots. Corresponding I.H.P., 9,270.

DATA U. S. TORPEDO BOAT DESTROYER *PAUL JONES.*

Bottom.	Indicated H.P.		Receiver pressures, pounds absolute.				Vacuum, inches of mercury.		I = 93½ Coal.				G. S. in use, sq. ft.
	Main engines.	Collective.	1st Receiver.		2d Receiver.				Tons per day.	Lbs. per hour.	Lbs. per H.P. hr.	Lbs. per sq. foot G. S. per hr.	
			S.	P.	S.	P.	S.	P.					
Clean.	360	420	15	15	5	5	26	26	15.914	1,325	3.15	8.27	160
Clean.	400	450	15	15	5	5	26	26	15	1,400	3.11	8.8	160
Foul.	520	580	15	15	7½	7½	26	26	15	1,400	2.41	8.8	160
Covered with barnacles.	500	550	15	15	7½	7½	26	26	14.5	1,353	2.46	8.7	160
Covered with barnacles.	1,379	1,454	45	45	11½	11½	27	27	39	3,640	2 5	22.75	160
Covered with barnacles.	.....	.....	20	20	12	12	27	27	14	1,307	.....	.....	160
Covered with barnacles.	.....	.....	...	...	...	...	...	...	15	1,400	.....	8.8	160
Covered with barnacles.	.....	.....	...	...	...	...	...	...	17	1,586	.....	.....	160
Covered with barnacles.	.....	.....	...	...	...	...	...	...	17	1,586	.....	.....	160
Covered with barnacles.	.....	.....	...	...	...	...	...	...	.....	.....	.....	.....	160
Very foul.	1,572	1,672	43	43	10	7½	28	28	42.5	3,965	2.37	24.8	160
Very foul.	678	728	21	21	7½	10	27	28	23.9	2,275	3.12	14.2	160
Very foul.	808	858	26	30	7½	10	26	28	24	2,280	2.53	14.3	160
Clean.	360	420	26	17	7½	5	27	27	15	1,400	.....	.....	160
Clean.	1,591	1,691	55	45	15	10	27½	28	45	4,200	2.48	26.2	160
Clean.	771	800	26	20	7	4	28	28	22	2,053	2.56	12.8	160
Clean.	203	263	15	15	7	5	26	26	10.5	980	3.72	12.25	80
Clean.	1,350	1,450	34	30	7	6	28	28	34.1	3,183	2.2	20	160
Clean.	725	825	28	16	7	4	26	27	30	2,800	3.4	17.5	160
Clean.	900	1,000	27	25	8	7	27	28	31.2	2,912	2.91	18.2	160
Clean.	717	800	23	20	7	7	27	28	32.1	3,000	3.75	18.75	160
Clean.	400	500	21	17	7	7	27	28	16.8	1,568	3.16	9.9	160
.....	.....	.....	...	...	...	...	...	...	.....	.....	.....	.....	...
.....	.....	.....	...	...	...	...	...	...	.....	.....	.....	.....	...
Moderately foul.	550	620	23	20	7	5	27	28	24	2,240	3.61	14	160
Moderately foul.	1,400	1,500	40	37	10	12	28	29	41	3,827	2.55	24	160
Moderately foul.	2,054	2,200	45	45	15	15	28	28	.....	.....	.....	.....	80
Moderately foul.	2,344	2,500	40	40	11	15	28	28	.....	.....	.....	.....	160
.....	3,050	3,250	...	...	...	...	...	...	.....	.....	.....	.....	...
Moderately foul.	6,613	6,813	85	86	30	30	27	26	187	17,600	2.7	55	320
.....	1,971	2,050	...	...	...	...	...	...	.....	.....	.....	.....	...
Moderately foul.	1,112	1,172	27	28	10	11	28	28	25	2,333	1.99	14.6	160

Maximum speed attained, 330 R. P. M. = 27.8 knots. Corresponding I.H.P., 9,270.

Lbs. per sq. foot G. S. per hr.	G. S. in use, sq. ft.	Draft, inches.	Miles per ton.	Cruising radius miles, 200 tons.	Kind of coal.	Cut offs.							
						Starboard.				Port.			
						H.	M.	1 L.	2 L.	H.	M.	1 L.	2 L.
8.27	160	Natural.	16.93	3,386	Cardiff.	.5	.5	.5	.5	.5	.5	.5	.5
8.8	160	Natural.	16.9	3,360	Cardiff and Welsh.	.5	.5	.5	.5	.5	.5	.5	.5
8.8	160	Natural.	13	2,600	Pocahontas.	.4	.6	.8	.8	.4	.6	.8	.8
8.7	160	Natural.	13.3	2,660	Pocahontas and Welsh.	.4	.6	.8	.8	.4	.6	.8	.8
22.75	160	1	7.75	1,550	Pocahontas.	.4	.6	.8	.8	.4	.6	.8	.8
.....	160	0	13.28	2,656	Pocahontas.	.4	.6	.8	.8	.4	.6	.8	.8
8.8	160	...	.....	.....	Pocahontas.	...	...	...	...	...	...	...	...
.....	160	...	.....	.....	Cardiff.	.5	.6	.7	.7	.5	.6	.7	.7
.....	160	...	.....	.....	Cardiff.	.5	.6	.7	.7	.5	.6	.7	.7
.....	160	...	.....	.....	.....	...	...	...	...	...	...	...	...
24.8	160	1	7.27	1,454	Cardiff.	.5	.6	.7	.7	.5	.6	.7	.7
14.2	160	½	9.4	1,880	Cardiff.	.5	.6	.7	.7	.5	.6	.7	.7
14.3	160	½	10.57	2,114	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4
.....	160	0	16	3,200	Cardiff.	.4	.4	.4	.4	.5	.5	.5	.5
26.2	160	1	9.6	1,920	Cardiff.	.4	.4	.4	.4	.5	.5	.5	.5
12.8	160	¼	14.29	2,658	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4
12.25	80	0	15.7	3,140	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4
20	160	½	11.3	2,260	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4
17.5	160	¼	11.04	2,208	Cardiff and Nanaimo.	.4	.4	.4	.4	.4	.4	.4	.4
18.2	160	¼	11.3	2,260	Cardiff and Nanaimo.	.4	.4	.4	.4	.4	.4	.4	.4
18.75	160	¼	9.9	1,980	Nanaimo.	.4	.4	.4	.4	.4	.4	.4	.4
9.9	160	0	15.5	3,106	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4
.....	...	...	.....	.....	.....	...	...	...	...	...	...	...	...
.....	...	...	.....	.....	.....	...	...	...	...	...	...	...	...
14	160	0	11.17	2,234	Nanaimo.	.4	.4	.4	.4	.4	.4	.4	.4
24	160	¼	8.9	1,780	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4
.....	80	2	.....	.....	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4
.....	160	2	.....	.....	.....	.4	.5	.4	.4	.5	.5	.5	.5
.....	...	...	.....	.....	.....	...	...	...	...	...	...	...	...
55	320	2½	3.27	654	Cardiff.	.7	.7	.7	.7	.10	.10	.10	.10
.....	...	...	.....	.....	.....	...	...	...	...	...	...	...	...
14.6	160	¼	12	2,400	Cardiff.	.4	.4	.4	.4	.4	.4	.4	.4

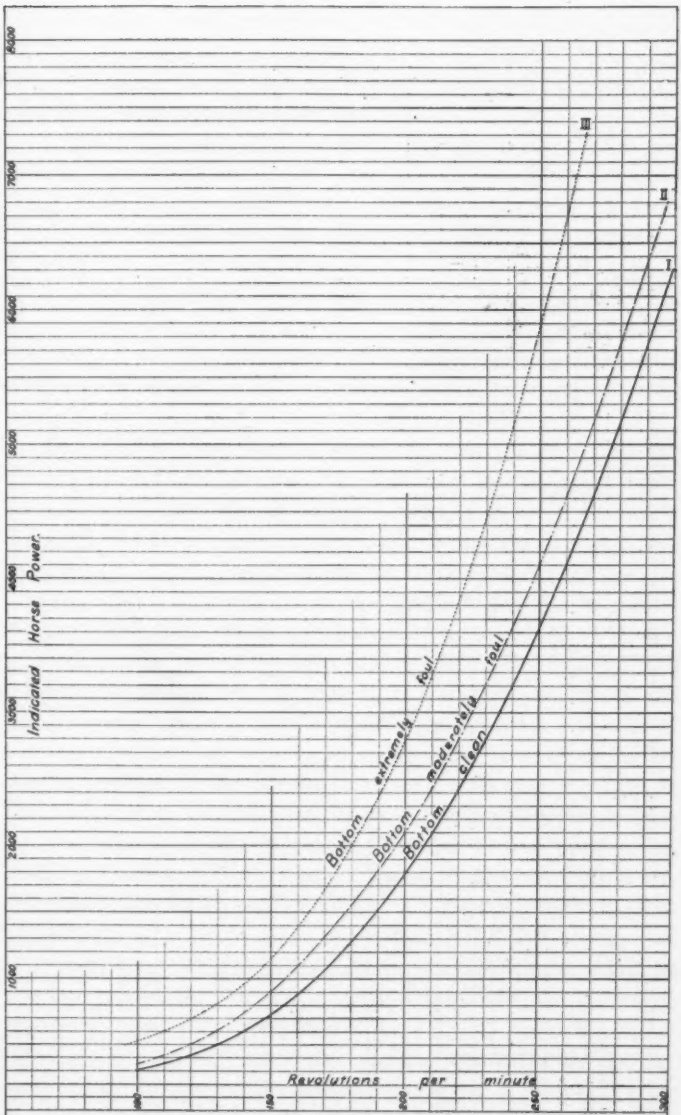

Indicated Horse Power.
Revolutions per minute
III
II
I
Bottom extremely foul
Bottom moderately foul
Bottom clean

Fig. I.

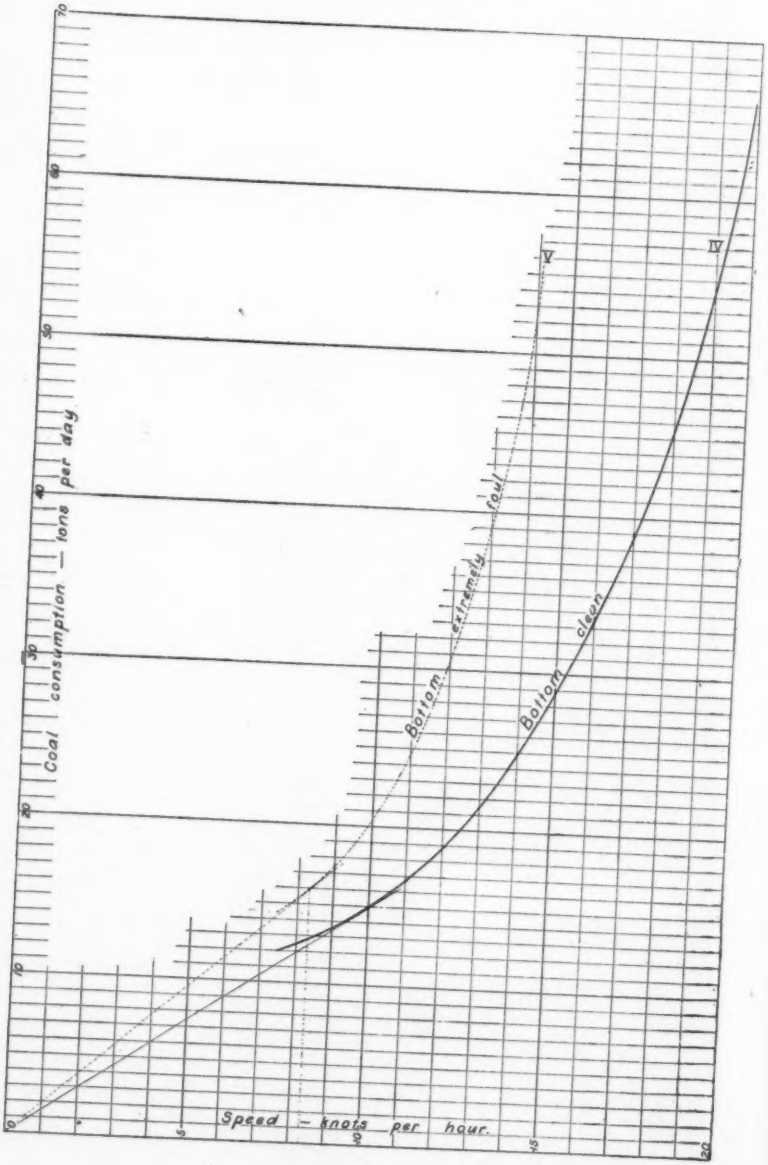

Coal consumption — tons per day
Speed — knots per hour.
Bottom extremely foul
Bottom clean
V
IV

Fig. 2.

and counters would give them. This curve coincides exactly with a theoretical curve where $HP. = C\,(\text{R.P.M.})^3$ the value of C of course being obtained by substituting horsepower and revolutions as actually observed.

Curve II is made from observations when the bottom was moderately foul, and in the same condition. This condition was made possible by the fact that the vessel was in warm water for two months soon after coming out of dry dock. During these two months she grew a crop of barnacles, about ¼ to ½ inch in height. Then she went to Puget Sound where the water was cold (about 50 degrees Fahrenheit). There barnacles ceased to grow, and no difference could be detected in the condition of her bottom from November, 1904, to April, 1905.

Curve III is made from observations with a very foul bottom. In this case also the foul condition was constant, being caused by a growth of large barnacles 2 to 3 inches in height. After leaving Panama, the barnacles did not grow perceptibly. Two weeks were spent in fresh water, the Columbia River, Oregon, which effectually killed the barnacles. But they did not drop off, and remained attached to the bottom until the vessel was next docked. It seemed that in this condition the bottom was as foul as it could get, so far as any effect on the speed of the vessel was concerned. It will be seen from Curve III that with a very foul bottom the horsepower required for any speed is about *double* that required for the same speed with a clean bottom. This, of course, takes into consideration the increased slip due to foul bottom. It also shows that the maximum speed attainable with a foul bottom is 23 knots as compared to 29 knots with a clean bottom.

It would seem that curves Nos. I and III may be taken as the two extremes. In any intermediate condition of the bottom one accurately determined point will be sufficient to establish an approximate curve for that condition of the bottom, using the law of the cube of the speed. This has actually been done in practice on this vessel, and has given results

which coincide with actual observations. Such curves are of great value when it comes to estimating the coal required for a certain length of run, the highest speed permissible with the coal supply on board, and finally as a check on the manner of firing. The close agreement of observed points with the theoretical curve based on the cube of the speed law seems sufficient evidence to establish the fact that that law holds good for practical purposes. It seems scarcely necessary to invite attention to the fact that most of the resistance of a vessel of this class is due to a skin friction when her bottom is foul. If it is assumed that with a clean bottom the wave-making and skin resistance are nearly equal, then, with a foul bottom, where the total resistance is doubled, it is evident that the skin friction is about three times as great as the wave-making resistance.

Finally, while the cube of the speed rule does not apply to all vessels, and while theoretically it may not apply exactly to this one, practically it applies so well as to be very useful, which is all that is required in practice.

COAL CONSUMPTION AND ECONOMY.

When in port with steam up during the entire twenty-four hours, the coal consumption averages 3 tons per day. It never exceeds $3\frac{1}{2}$ tons. Generally fires are banked except during six hours of the twenty-four, so that the coal consumption is only $1\frac{1}{2}$ tons per day. Fig. 2, Curve IV, represents coal consumption at sea. Curve IV is the coal-consumption curve with a foul bottom. It is seen that the economical speed with a clean bottom should be 10 knots and with a foul bottom 8. In actual practice these speeds have been used, as this vessel was cruising in company with other vessels which could steam no faster.

Fig. 3 gives curves showing the effect of increased displacement on the slip. Revolutions per mile are used instead of percentage of slip, as it is often of practical value for navigation and other purposes to know the revolutions per mile. Curve VI was made by a series of comparisons between the

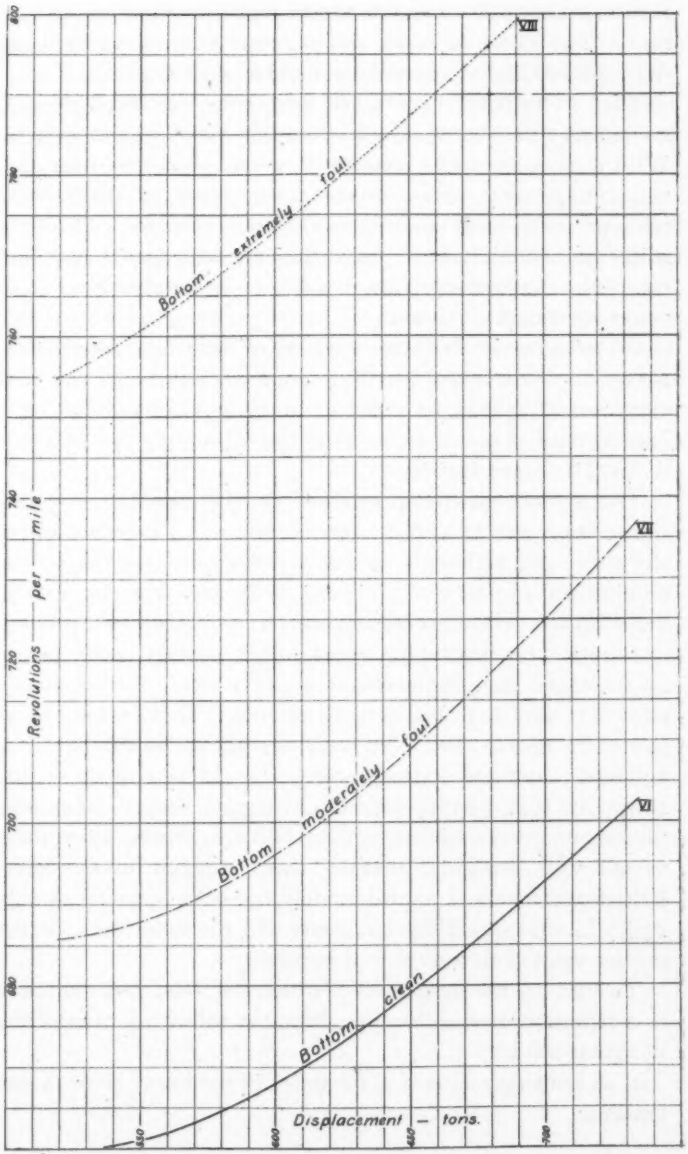

Revolutions per mile
Displacement — tons.
Bottom extremely foul
Bottom moderately foul
Bottom clean
VIII
VII
VI

Fig. 3.

revolution counters and the patent log, thus eliminating current. The effect of wind and sea was eliminated by using data observed in comparatively smooth weather.

That a destroyer can be self sustaining has been demonstrated on a number of occasions for periods of several months. With a complete outfit of stores it would be possible for this vessel to perform active service for a period of six months without going near another vessel or navy yard. The only stores she would have to get during that period are coal and oil. The evaporating plant is capable of supplying all fresh water needed at all times.

On account of the large number of bearings the oil consumption seems large, twenty gallons per day being the least ever used at ten knots. But as much as 1,000 gallons have been carried at one time, so that the oil supply can be made to last fifty steaming days.

The highest speed ever attained on this vessel during this commission was 27 knots. Her bottom was somewhat foul at the time, and, although indicator cards were not taken, the revolutions and receiver pressure indicated that she was developing her maximum horsepower. It would not be far wrong to estimate her maximum speed under average conditions of foul bottom and displacement at 26 knots. As previously shown, it may at times, with an extremely foul bottom, be as low as 23 knots. But even with the above limitations it is believed that these destroyers are today the best in the world. It appears that a happy medium as regards length, beam, displacement, power and strength of hull was struck when these vessels were designed, making them superior to the latest British destroyers of approximately the same size and of only 25 knots trial speed. What speed will the latter make under service conditions with a foul bottom?

To sum up, the destroyers of which the *Paul Jones* is taken as a representative of the type, have the following capabilities in actual service:

1. A cruising radius of 3,300 miles, at ten knots, with a clean bottom.

2. A cruising radius of 2,700 miles, at eight knots, with a foul bottom.
3. A maximum speed of about 28 knots, with a clean bottom.
4. A maximum speed of about 23 knots, with a foul bottom.
5. Ability to keep at sea in all weather.
6. Comfortable quarters for officers and men.
7. Self-sustaining power for a period of several months.

Thus it is seen there is but a narrow margin between the maximum speed of the fastest heavy ships under favorable, and the maximum speed of a destroyer under adverse conditions. So, if we are to have any more destroyers, it is hoped that their acceptance trial speed will not be less than twenty-nine knots.

TEST OF PIPE JOINTS.

The following description of tests, made at the works of Dienelt & Eisenhardt, Philadelphia, is taken from a report made by Commander T. F. Burgdorff, U. S. N., member.

The tests consisted in expanding, flaring and facing a 20-inch lap-welded steel pipe, ⅜-inch thick, into a grooved steel flange by a Lovekin pipe-flanging machine, and in testing various forms of flanges of 4- and 5-inch pipe by hydraulic pressure for tightness between flange and pipe, and for determining the force necessary to detach the flanges from their pipes. These tests were conducted at the above named works in my presence on February 14th and 16th, 1905.

The Lovekin pipe-flanging machine, by which the 20-inch steel pipe was secured to its steel flange, resembles a large lathe in appearance. It is about 35 feet 6 inches long, 5 feet 7 inches wide, and about 7 feet high; weighs, approximately, with the set of tool heads, 20 tons, and is capable of expanding into flanges pipes varying from 12 to 30 inches in diameter and in lengths up to 20 feet.

It consists essentially of three parts, securely bolted together, viz:

1st. A heavy head piece, with hinged cap, by which the pipe flange is securely clamped in accurately-fitting flange dies, to prevent the flange from expanding with the pipe. These flange dies are made in half sections, of a uniform outside diameter to fit the head piece, and of an inside diameter to fit the circumference of each size of pipe flange. To fit these flange dies accurately the outer surfaces of the pipe flanges are turned true. This part is also provided with a gripping device to prevent the pipe from turning. A view of the head is seen in the middle part of Fig. 1, which is taken from the "The Iron Age," of February 16, 1905.

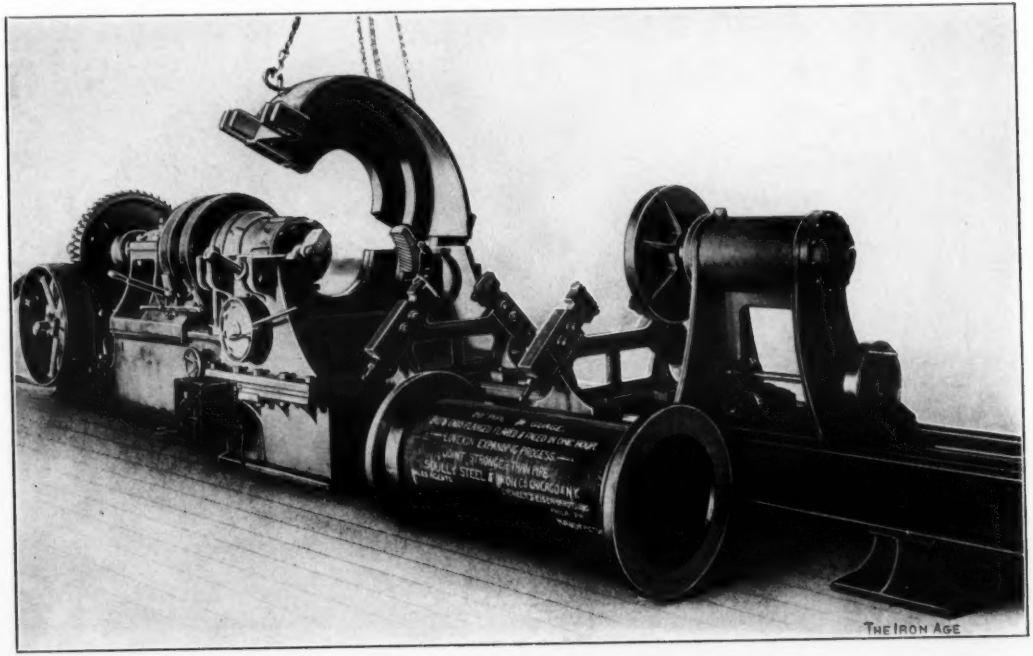


Fig. 1.

THE IRON AGE

Fig. 2.

2d. A two-channel beamway fitted with central rack, on which the pipe is supported by means of adjustable roller blocks, and which also supports an adjustable hydraulic ram, by means of which the pipe may be forced into its flange and kept from backing out while being expanded. A view of this part is seen on the right-hand end of Fig. 1.

3d. The mechanism for supporting and operating the expanding tool. This consists of a longitudinal cast-iron frame with central-feed screw for moving the carriage which supports the operating tool and a pedestal for supporting the shaft by which the operating tool is revolved. A view of this part of the machine is seen in Fig. 2, also taken from "The Iron Age" of February 16, 1905.

Power is derived from a 25-H.P. electric motor through a belt, or may be obtained from a countershaft if desired. By reversing the current the machine may be run in either direction.

The belt pulley is secured to a transverse shaft fitted with a worm, working in an oil bath, and gearing with a worm-wheel, which is secured to a sleeve working in a bearing of the pedestal, and transmits motion to the main shaft of the machine through feathers to allow the shaft to move longitudinally through the pedestal as it moves back and forth with the tool carriage, in which it is securely bedded by means of a fixed and a screwed collar. A projection of this shaft beyond the tool-carriage bearing is secured by two keys to the inside of a hollow cast-iron shank or sleeve in which the expander spindle surrounded by the flaring sleeve is carried.

To the free end of the shank is secured by means of two keys and two set screws the collar flange, to whose face the tool head is bolted, the tool head consisting of a hollow shell in which the expanding and flaring rollers are located. The tool heads are of different diameters for the various diameters of pipe to be operated upon, and each diameter of tool head requires its particular diameter of collar flange.

The tool head consists of a hollow cast-iron shell, conical for a short length at an angle of about 20 degrees at its fixed

end for carrying the flaring rollers, and cylindrical through the remaining part for carrying the expanding rollers. The expanding rollers and flaring rollers, each five in number, are made of hard steel.

Inside of the cylindrical part of the tool head is located the expander cone of hard cast steel. This expander cone is secured to a spindle which extends back nearly the entire length of the hollow shank, the spindle being slotted near its inner end and fitted with a threaded key, which meshes through a slot in the shank with a finely-threaded feed nut surrounding the shank, the feed nut being held stationary by means of a friction band secured to the tool carriage, while the shank and tool head are revolving to feed in the expander cone and force out the expander rollers while expanding the pipe into its flange.

Back of the expander cone in the tool head is located the flaring cone, which is secured to a sleeve surrounding the expander spindle, and is fed in a similar way as the expander cone, by a second feed nut surrounding the shank, by means of a second friction band secured to the tool carriage.

These two feed nuts fit loosely on the shank and when not held by the friction bands revolve with it. They are longitudinally secured in position by two screwed collars which are secured to the shank each by two set screws, and by a fixed collar of the shank on the tool-head side. The collar between the two feed nuts rests on a roller bearing secured to the tool carriage to support the overhang of the revolving tool.

Gauges are fitted to the keys of the expander spindle and flaring sleeve by which the amount of work done by the expanding and flaring rollers can be ascertained.

A facing tool is secured near the free end of the cylindrical part of the tool head when it is desired to face off the end of the pipe in the flange.

The tool carrriage consists of a pedestal, which is movable along the frame of the machine, and can be moved in either direction by means of the central feed screw, either by a hand wheel on the side of the machine frame or by gearing from the

end of the transverse pulley shaft. The tool carriage, however, is only moved to enter the tool head to its desired position in the pipe, and during the operations of expanding and flaring is thrown out of gear and remains stationary. It is fed by the hand wheel, however, while the end of the pipe is being faced off.

On February 14th a length of 20-inch welded-steel pipe, $\frac{3}{8}$ inch thick, together with its steel flange, had been secured in position in the machine just described, but without the hydraulic ram being in contact with the free end of the pipe. The tool head had also been secured to the machine.

After running the tool head into the pipe for position and starting the motor for turning the tool head, the feed for the expanding rollers was put on, and the pipe was expanded into its flange from 11·21 to 11·29 by the watch, or 8 minutes; the motor was then reversed and the expander rollers collapsed by 11·33 A. M., or 4 minutes more. The tool head was then run further into the pipe until the flaring rollers were in position, and the flaring of the pipe was completed by 11·39 A. M. The motor was again reversed and the flaring rollers collapsed by 11·42 A. M. The flaring rollers were then secured by screwed clamps and the expanding rollers by a belt by 11·44 A. M. A facing tool was then inserted into the tool head near its end and the end of the pipe was faced off even with the flange from 11·47 to 11·53 A. M., after which the tool head was withdrawn from the pipe and the machine stopped at 11·55 A. M.

The whole operation from the time the tool head had entered the pipe, of expanding, flaring and facing the pipe, from 11·21 to 11·55 A. M., consumed a period of 34 minutes. The surfaces operated upon remained cool to the touch. The expanded and flared surfaces of the pipe were perfectly smooth, the flared surface making an angle of about 20 degrees with the axis of the pipe. The pipe was left in the machine after the operation was completed.

For expanding and flaring pipes of smaller diameter the operating mechanism and jaws for holding the pipe flanges

are mounted on a single cast-iron base, with a motor at the rear end, driving the machine by belt and cone pulleys or by means of countershafts over head provided with cone pulleys, as may be desired.

In general, these machines are made in three sizes—the smallest size for expanding pipe from 2 inches to $7\frac{1}{2}$ inches diameter, the intermediate size for expanding pipe from 8 to 16 inches in diameter, and the largest size for expanding pipe up to 30 inches in diameter.

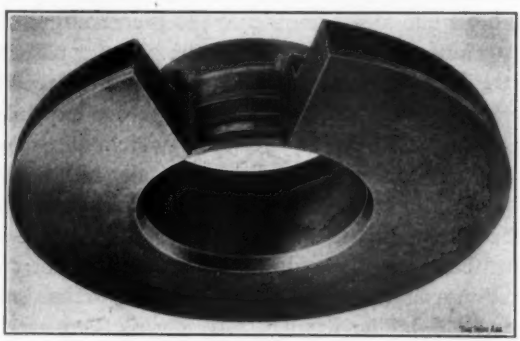


Fig. 3

A view of an expanded and flared pipe end is shown in Fig. 3.

The following tests were made on February 14th and 16th, 1905, to test the tightness of various pipes and flanges under hydraulic pressure, and then to determine the pressure required to force the flanges off their pipes.

To test the tightness under hydraulic pressure the pipes were blank flanged, as shown on the accompanying illustrations, and pressures were obtained by pumping with an hydraulic jack against the top crosshead of the pump frame, the pipe under test being connected with the hydraulic jack and a pressure gauge, as shown in the accompanying illustration, Fig. 4.

To make the second test, that of forcing the flange off its pipe, the blank flange was removed from one end of the pipe,

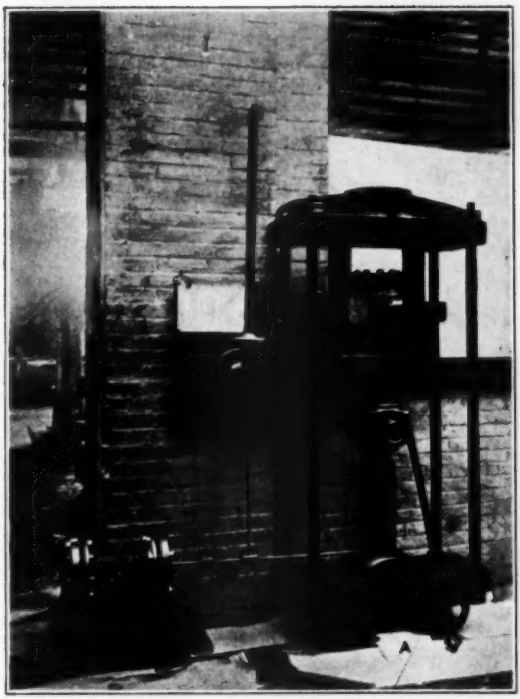


Fig. 4.

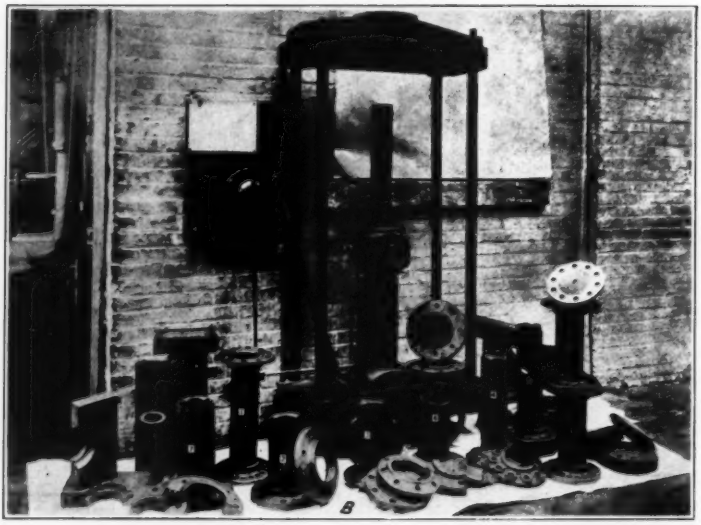


Fig. 5.

and a metal bar, of somewhat greater length than the pipe, and of such diameter as to be loose in the pipe, was placed vertically on the head of the hydraulic jack, as shown on the accompanying illustration, Fig. 5, and was covered by the pipe under test, the upper end of the bar pressing against the blank flange at the upper end of the pipe, while the lower flange of the pipe was braced down from the upper crosshead of the pump frame, as shown in Fig. 4. Fig. 4 shows the hydraulic pump rigged for both of the above tests, but only one test was carried on at a time.

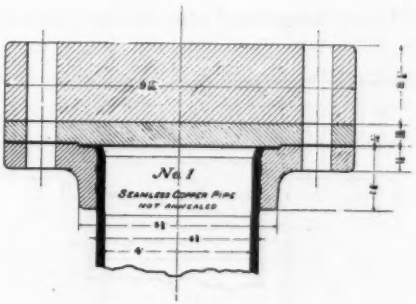


Fig. 6.

Pipe No. 1 (Fig. 6), consisted of a seamless copper pipe, 4 inches inside diameter, $\frac{3}{16}$ inch thick and about $18\frac{5}{8}$ inches long, expanded and flared without previous annealing into a forged-steel flange at each end, the flange with its collar at the bore being $1\frac{3}{4}$ inches thick and $\frac{11}{16}$ inch thick beyond the collar, and containing two rectangular grooves $\frac{3}{16}$ wide and $\frac{1}{32}$ inch deep. The flanges were counterbored at their face to an angle of 20 degrees for a length of about $\frac{1}{4}$ inch, and countersunk $\frac{1}{16}$ inch for a $5\frac{1}{2}$ inch diameter. The blank flanges were made in two parts, a forged-steel plate $\frac{21}{32}$ inch thick for a $5\frac{1}{2}$ inch diameter and $\frac{19}{32}$ inch thick outside of this diameter was backed by a cast-iron flange $2\frac{1}{8}$ inches thick; both were of an extreme diameter of $9\frac{17}{32}$ inches and $7\frac{1}{2}$ inches in diameter at bolt centers, and were bolted to the flange of the pipe by

ten $\frac{3}{4}$-inch steel bolts, with a thin copper gasket placed in the counter-sunk part of the pipe flange.

On pumping up the cold-water pressure, one of the gaskets began leaking at a pressure of 3,200 pounds per square inch, and the pressure could not be raised above 3,600 pounds on account of this leak. After the pressure had been released, one of the pipe flanges was found loose on the pipe. This pipe was re-expanded in its flanges, and in making the second test for forcing the flanges off the pipe, the upper flange slipped over the pipe at a total pressure on the ram of 24.73 tons, produced by a pressure in the pump of 3,600 pounds per square inch. The lower flange had also just started to move.

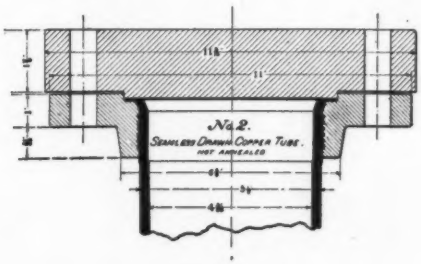


Fig. 7.

Pipe No. 2 (Fig. 7), consisted of a seamless-drawn 5-inch copper pipe, measuring $4\frac{31}{32}$ inches inside and $5\frac{1}{2}$ inches outside diameter and about $11\frac{3}{16}$ inches long, expanded and flared without previous annealing into a forged-steel flange at each end, the flange with its collar at the bore being $1\frac{31}{32}$ inches thick and 1 inch thick outside the collar, and containing six flattened V grooves, $\frac{1}{16}$ inch wide at the bottom, $\frac{1}{16}$ inch deep and $\frac{3}{16}$ inch pitch. The flanges were counterbored at the face to an angle of twenty degrees for a length of about $\frac{11}{32}$ inch, and countersunk $\frac{7}{32}$ inch for a $6\frac{1}{2}$-inch diameter; the face of the countersunk part containing four small circular V-shaped grooves for securing the gaskets. The blank flanges were of cast iron, were turned to fit into the countersunk part of the pipe flange, were $1\frac{7}{8}$ inches thick at

the bolt holes, $8\frac{15}{16}$ inches in diameter at bolt centers, and $11\frac{5}{16}$ inches over all, and were secured by eight $\frac{3}{4}$-inch steel bolts with a thin copper gasket placed in the countersunk part of the pipe flange.

On pumping up the cold-water pressure, this pipe began leaking at a pressure of 1,800 pounds per square inch between the pipe and flange collar, and increased $\frac{1}{32}$ of an inch in length between center-punch marks, originally $10\frac{21}{32}$ inches apart, without increasing in diameter. After this pipe was re-rolled in its flanges it began leaking through the gasket at a pressure of 2,800 pounds per square inch, and through a porous spot in the blank flange, the expanded joints remaining tight. The diameter of the pipe had increased $\frac{1}{64}$ of an inch at this pressure, as had also the length between center-punch marks.

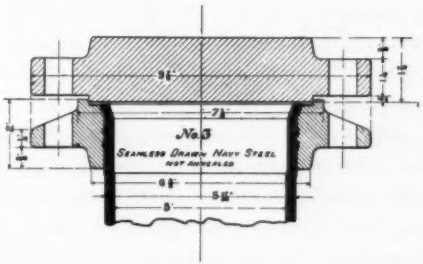


Fig. 8.

Without further re-rolling, this pipe was subjected to the second test for forcing off the flanges, and the upper flange slipped off the pipe at a total ram pressure of 15.188 tons, produced by a pressure in the pump of 2,200 pounds per square inch, the indications of the pipe showing that the pipe had been expanded only into the two lower grooves of the flange.

Pipe No. 3 (Fig. 8) consisted of a 5-inch seamless-drawn steel pipe, as supplied to the Navy, measuring $5\frac{9}{16}$ inches outside diameter, and $\frac{17}{64}$ of an inch thick, and about $12\frac{1}{8}$ inches long, expanded and flared, without previous annealing, into a forged-steel flange at each end, the flange with its collar at the bore

being 2 inches thick, countersunk $\frac{1}{8}$ of an inch on its face to a $6\frac{1}{2}$-inch diameter, and cut away on its face $\frac{5}{16}$ of an inch beyond the $7\frac{1}{8}$-inch diameter, and tapering beyond this to a thickness of $\frac{1}{2}$ inch at its circumference of $9\frac{7}{8}$ inches diameter. The flanges were counterbored at the face to an angle of 20 degrees for a length of about $\frac{7}{16}$ of an inch, and the counterbore was countersunk for a length of about $\frac{5}{16}$ of an inch to form an extra groove for the flared portion of the pipe; the cylindrical bore of the flange was cut with two rectangular grooves, $\frac{5}{32}$ of an inch wide and about $\frac{3}{64}$ of an inch deep, the $\frac{3}{16}$ of an inch ridge between these grooves being rounded off to a radius of about $\frac{5}{32}$ of an inch. The countersunk face of the flange contained four small V grooves for holding the gasket. The blank flanges were of forged steel, were turned to fit into the countersunk face of the pipe flange, were $1\frac{7}{8}$ inches thick through $6\frac{3}{8}$ inches diameter and $1\frac{1}{16}$ inches thick at the outer portions about the bolt holes, and were seeured by eight $\frac{3}{4}$-inch steel bolts with a thin copper gasket placed in the countersunk part of the pipe flange.

On pumping up the cold-water pressure a leak occurred through one of the gaskets at 600 pounds per square inch, and increased to such an extent that it was impossible to raise the pressure above 3,800 pounds per square inch, the expanded joints showing no leak at this pressure. The pipe at this pressure had lengthened about $\frac{1}{64}$ of an inch.

After fitting the blank flanges with $\frac{1}{16}$-inch lead gaskets this pipe was again subjected to hydraulic pressure, and when a pressure of 4,100 pounds per square inch had been attained the gasket at the near end to the pump began leaking slightly. At a pressure of 4,800 pounds per square inch the flange at the far end of the pipe slipped at the top of the pipe, although there had been no leaks through the expanded joints up to this time. The pipe at this pressure had expanded $\frac{5}{32}$ of an inch in diameter near the middle of its length; the pipe had also increased about $\frac{21}{32}$ of an inch in a length of 10 $\frac{3}{16}$ inches.

After the pressure had been taken off completely, it was again pumped up, and the cock-billed flange began leaking

through the expanded joint at a pressure of 950 pounds per square inch.

On applying the second test for forcing the flanges off the pipe the cock-billed flange slipped off the pipe at a total pressure of 34.36 tons on the ram produced by a pressure in the pump of 5,000 pounds per square inch, the pipe showing that the expanded metal had not been well forced into the flange grooves.

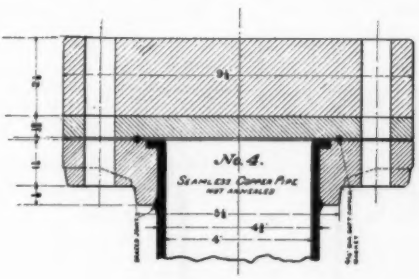


Fig. 9.

Pipe No. 4 (Fig. 9) consisted of a 4-inch seamless-drawn copper pipe 4 inches inside diameter, $\frac{3}{16}$ of an inch thick and about $18\frac{3}{8}$ inches long between flange faces. This pipe was previously annealed; was hammer pened and beaded by the usual old method, and was brazed to its composition flanges.

The flange with its collar at the bore was $1\frac{3}{4}$ inches thick, and tapered beyond the collar to a thickness of $\frac{3}{4}$ of an inch at the diameter of the bolt-hole centers, and continued at that thickness to the circumference, whose diameter was $9\frac{1}{2}$ inches. The back of the flange was bossed around the bolt holes to a thickness of $1\frac{1}{4}$ inches; the face was recessed to a depth of $\frac{3}{16}$ of an inch for a diameter of 5 inches to receive the beaded end of the pipe, and the face was further grooved at the $5\frac{1}{2}$-inch diameter to receive a $\frac{3}{16}$ of an inch soft copper wire for gasket.

The blank flanges were made in two parts, a forged-steel plate $\frac{1}{32}$ of an inch thick was backed by a cast-iron flange $2\frac{1}{8}$ inches thick at each end of the pipe, and were secured to the pipe flanges by ten $\frac{3}{4}$-inch steel bolts.

On pumping up the cold-water pressure this pipe began increasing in length at a pressure of 900 pounds per square inch, and began leaking through the gasket in the far joint from the pump at a pressure of 1,800 pounds per square inch. The pressure was discontinued after 2,200 pounds per square inch had been reached, when the pipe had increased $\frac{1}{8}$ of an inch in an original length of $17\frac{3}{32}$ inches between center-punch marks on the flanges and $\frac{1}{4}$ of an inch in diameter.

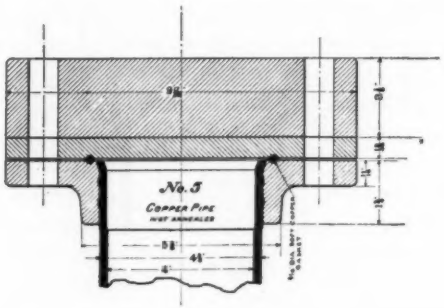


Fig. 10.

Subjected to the second test for stripping off the flanges, when a total pressure of 29.5 tons on the ram had been attained, produced by a pressure of 4,300 pounds per square inch in the pump, the pipe had stretched to such an extent that the center-punch marks had separated $1\frac{29}{32}$ inches, and the top flange was touching the crossbar of the pump frame. After readjusting the position of the pipe and again applying the pressure, the pipe broke about $\frac{1}{2}$ of an inch below the upper flange with a total pressure of 29.5 tons on the ram, the center-punched length of $17\frac{3}{32}$ inches had increased $2\frac{9}{32}$ inches, and the outer diameter of the pipe had been reduced to $4\frac{3}{8}$ inches. The brazing at the collars of the flanges was cracked lengthwise with the pipe in numerous places, and both pipe flanges were dished about $\frac{1}{4}$ of an inch, the circumference of the flanges being drawn $\frac{1}{2}$ of an inch further apart than the bores.

Pipe No. 5 (Fig. 10), consisted of a seamless-drawn 4-inch

copper pipe, cut from the same length of pipe as pipe No. 1, 4 inches inside diameter, $\frac{3}{16}$ of an inch thick and about $18\frac{5}{8}$ inches long, expanded and flared without previous annealing into a forged-steel flange at each end, the flanges being of the same description and dimensions as those on pipe No. 1.

This pipe was not subjected to hydraulic pressure, but was only subjected to the second or pulling test to force the flanges off the pipe. In this test the lower flange slipped at a total ram pressure of 28.175 tons, produced by a pressure in the pump of 4,100 pounds per square inch, partially shearing off the extruded pipe metal in the flange grooves and slipping over it. The upper flange had slipped but slightly. This pipe stretched to such an extent that it closed in on the mandrel, and had to be forced off.

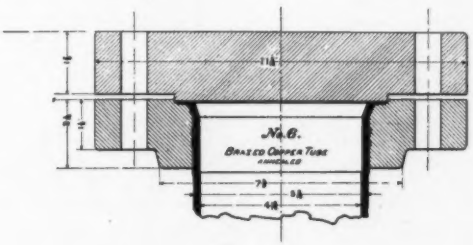


Fig. 11.

Pipe No. 6 (Fig. 11), consisted of a 5-inch brazed copper pipe, not uniformly round, measuring $4\frac{15}{16}$ inches inside diameter and $5\frac{5}{16}$ inches outside, and about $12\frac{5}{16}$ inches long, expanded and flared, after annealing, into a cast-iron flange at each end, the flange with its collar at the bore being $2\frac{1}{16}$ inches thick, and countersunk $\frac{1}{8}$ of an inch on its face to a $6\frac{1}{2}$-inch diameter. The flanges were counterbored at the face to an angle of 20 degrees for a length of about $\frac{7}{16}$ of an inch, and the counterbore was countersunk for a length of about $\frac{5}{16}$ of an inch to form an extra groove for the flared portion of the pipe. The cylindrical bore of the flange was cut with two rectangular grooves $\frac{5}{32}$ of an inch wide and about $\frac{3}{64}$ of

an inch deep, the $\frac{3}{16}$ of an inch ridge between these grooves being rounded off to a radius of about $\frac{5}{32}$ of an inch. The countersunk face of the flange contained four small V grooves for holding the gasket. The expanded portion of this pipe, it will be seen, was in every respect the same as that of the 5-inch steel pipe No. 3. The blank flange was of cast iron, turned to fit into the countersunk face of the pipe flange, where it was $2\frac{3}{32}$ inches thick, and $1\frac{7}{8}$ inches thick beyond this boss, and was secured to the pipe flange by eight $\frac{3}{4}$-inch steel bolts.

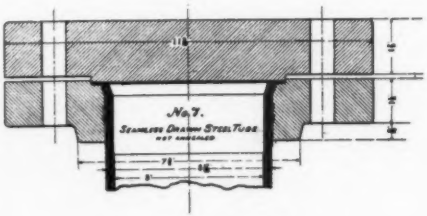


Fig. 12.

This pipe was not subjected to hydraulic pressure but was subjected only to the second or pulling test to force the flanges off the pipe. In this test when a total pressure of 34.36 tons had been attained on the ram, produced by a pressure of 5,000 pounds per square inch in the pump, the pipe broke throughout its circumference near the bottom of the flare in the lower flange, except through a circumferential length of about $2\frac{1}{4}$ inches where the break extended about $1\frac{1}{2}$ inches further from the end. This lower flange was later broken by a sledge. An examination of the pipe showed that the grooves of the flange had been well filled by the expanded portion of the pipe.

Pipe No. 7 (Fig. 12), consisted of a 5-inch seamless-drawn steel pipe, of the same character as pipe No. 3, and measured 5 inches inside diameter, $5\frac{7}{32}$ inches outside diameter, and about $12\frac{5}{16}$ inches long. It was expanded and flared without previous annealing into a cast-iron flange at each end, the flanges being in every respect the same as those of Pipe No. 6, excepting that due to slight difference of the outside diame-

ter of the pipes. The blank flanges were also of the same material and dimensions as those of Pipe No. 6, and they were similarly secured by eight $\frac{3}{4}$-inch steel bolts.

This pipe was subjected only to the second or pulling test to force the flanges off the pipe. In this test when a total pressure of 32.98 tons had been attained on the ram, produced by a pressure of 4,800 pounds per square inch in the pump, the lower flange slipped, slightly shearing off the extruded collars of the expanded pipe, the metal of which had not been well forced into the flange grooves during the expansion. The upper flange was not started. The flanges of this pipe were then broken with a sledge.

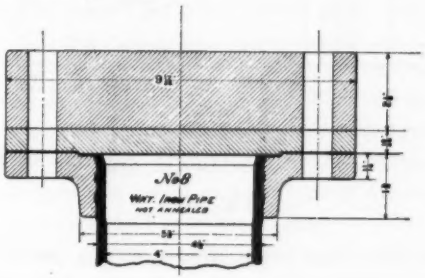


Fig. 13.

Pipe No. 8 (Fig. 13), consisted of a 4-inch wrought-iron pipe, measuring 4 inches inside diameter, $4\frac{1}{2}$ inches outside diameter and about 13 inches in length, expanded and flared without previous annealing into a forged-steel flange at each end, the flange with its collar at the bore being $1\frac{3}{4}$ inches thick and $\frac{11}{16}$ of an inch beyond the collar. The face of the flanges were countersunk $\frac{1}{16}$ of an inch to a $5\frac{1}{2}$-inch diameter and contained four small V grooves for holding the gaskets. The flanges were counterbored at the face to an angle of 20 degrees for a length of about $\frac{1}{4}$ of an inch; the cylindrical part of the bore was cut with two rectangular grooves $\frac{3}{16}$ of an inch wide and $\frac{1}{32}$ of an inch deep with a ridge $\frac{3}{8}$ of an inch wide between them. The blank flanges were made in two parts, a forged-steel plate $\frac{11}{16}$ of an inch thick to fit into the countersunk part

of the pipe flange and $\frac{19}{32}$ of an inch thick beyond that was backed by a cast-iron flange $2\frac{1}{8}$ inches thick and secured to the pipe flange by ten $\frac{3}{4}$-inch steel bolts.

This pipe was submitted to the hydraulic test only, and is said to have been re-rolled after a previous pressure of 3,600 pounds per square inch. At the present test it began to leak under the flange away from the pump when the pressure had reached 2,000 pounds per square inch, and the flange slipped $\frac{1}{8}$ of an inch toward the end of the pipe.

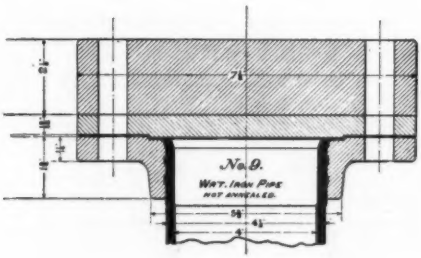


Fig. 14.

It will be seen that pipes Nos. 1, 2, 3, 4 and 8 were subjected to the hydraulic test to determine their capacity to withstand leaks from within, and that pipes 1, 2, 3, 4, 5, 6 and 7 were subjected to the ram test for stripping the flanges off the pipes. Thus, while pipes 1, 2, 3 and 4 were subjected to both tests, pipes 5, 6 and 7 were subjected to the stripping test only, and pipe No. 8 was subjected to the hydraulic test only. Pipes Nos. 1, 2, 4, 5 and 6 were of copper, while pipes 3 and 7 were of steel, and pipe No. 8 of wrought iron. Pipes 1, 4, 5 and 8 were 4-inch pipes, and pipes 2, 3, 6 and 7 were 5-inch pipes. Pipes 1, 2, 3, 4, 5 and 7 were seamless-drawn, pipe No. 6 a brazed copper, and pipe No. 8 a lap-welded iron pipe. Pipe No. 4 was hammer pened and beaded by the usual old method, and brazed to its composition flanges, while all the other pipes were expanded and flared by machine. The flanges were of various materials; those of pipes 1, 2, 3, 5 and 8 were of forged steel; those of No. 4 composition, and those of 6 and 7 of cast

iron. With the exception of the flanges of No. 4 pipe all were grooved in the bore and flared at the face. Those of pipes Nos. 1, 3, 5, 6, 7 and 8 were each fitted with two rectangular grooves, the ridge between these grooves being of rectangular section on Nos. 1, 5 and 8, while on Nos. 3, 6 and 7 this ridge was rounded off to facilitate the flow of the extruded pipe metal into the grooves. The flanges of No. 2 pipe were fitted with six flattened V grooves.

The following is a synopsis of the pipe tests.

HYDRAULIC TEST.

No. 1 Pipe.—Lead gasket began leaking at 3,200 pounds and pressure could not be raised above 3,600 pounds, and one flange became loose.

No. 2 Pipe.—Began leaking between pipe and flange at 1,800 pounds pressure per square inch, and after re-expanding pipe in flange it began leaking through gasket at 2,800 pounds.

No. 3 Pipe.—Began leaking through the gasket at 600 pounds and pressure could not be raised above 3,800, there being no leak between pipe and flange. After fitting new lead gasket, one gasket began leaking at 4,100 pounds pressure per square inch, and one flange slipped at 4,800 pounds pressure per square inch.

No. 4 Pipe.—Began leaking through one gasket at 1,800 pounds per square inch, and pressure discontinued at 2,200 pounds per square inch.

No. 5 Pipe.—No test.

No. 6 Pipe.—No test.

No. 7 Pipe.—No test.

No. 8 Pipe.—This pipe is said to have been re-rolled after having been subjected to a previous test of 3,600 pounds per square inch. At present test began to leak between pipe and one flange at 2,200 pounds per square inch and flange began slipping.

STRIPPING TEST.

No. 1.—After expanding pipe in flange, upper flange slipped at 24.73 tons ram pressure.

No. 2.—Upper flange slipped off pipe at 15.188 tons ram pressure. Pipe metal did not extrude into all the grooves, only the two lower grooves being full.

No. 3.—Cock-billed flange was slipped off pipe at ram pressure of 34.36 tons. Pipe metal had not been well forced into flange grooves.

No. 4.—At 29.5 tons ram pressure pipe had stretched enough to touch crosshead on top of frame, and after re-adjusting its position, when a ram pressure of 29.5 tons was again attained, the pipe broke about one-half inch below top flange.

No. 5.—Lower flange slipped at ram pressure of 28.175, tons, partially shearing off extruded pipe metal and partially slipping over it.

No. 6.—Pipe broke throughout circumference near the inner end of the flare in lower flange at a total ram pressure of 34.36 tons. Grooves had been well filled with extruded metal.

No. 7.—Lower flange slipped slightly at a total ram pressure of 32.98 tons, shearing off the extruded collars, which had not well filled the grooves.

No. 8.—No test.

The object of the pipe tests was to show the superior strength or holding power of the flanges of the machine-expanded pipe over that of the hammer-pened and brazed one.

It will be seen from the hydraulic tests that of the machine-expanded pipes No. 2 began leaking between flange and pipe at a pressure of 1,800 pounds per square inch, and after re-expanding was tight between pipe and flange when the pressure was discontinued at 2,800 pounds on account of a leaky gasket and porous blank flange; that a flange on No. 1 pipe became loose at a pressure of 3,600 pounds, of No. 3 at 4,800 pounds and of No. 8 at 2,200 pounds, while the hammer-pened and brazed pipe No. 4 was tight between pipe and flange when the pressure was discontinued at 2,200 pounds on account of a badly leaking gasket.

In the ram or stripping tests one flange became loose by slipping on each of the machine-expanded pipes Nos. 1, 2, 3, 5 and 7, at total pressures varying from 15.188 tons in No. 2

to 34.36 tons in No. 3, the stripping pressure being 24.73 tons for No. 1, 28.75 tons for No. 5, and 32.98 tons for No. 7, while the machine-expanded pipe No. 6 broke throughout its circumference near the inner end of the flare in one of its flanges at a total pressure of 34.36 tons, and the hammer-pened and brazed pipe No. 4 broke throughout its circumference about $\frac{1}{2}$ inch below its top flange at a total pressure of 29.5 tons.

The greater elongation of No. 4 pipe, while undergoing the stripping test, was undoubtedly due to its having been annealed before it was hammered into its flanges. The elongation of No. 6 pipe, similarly annealed before expanding, was not ascertained. None of the other pipes were annealed before expanding.

Of the machine-expanded pipes the pipe metal was not well extruded into the flange grooves of pipes Nos. 2, 3 and 7, and of these, No. 2, a copper pipe, was the only pipe whose flanges were fitted with the flattened V grooves, and pipes Nos. 3 and 7 were of steel, which metal flows less readily than copper.

It can be readily seen, however, that the method of fitting pipes into their flanges by the expanding machine is much superior to the old method of hammer pening, the time necessary to perform the same operation is by it very much reduced, it causes much less strain on the metal of the pipe, and makes the work much more reliable. Of course, care must be taken that the expanding tool is centrally located within the pipe in expanding, and that the expanding is not carried so far as reduce the thickness of the metal of the pipe.

SELECTION AND USE OF CERTAIN APPARATUS AND MATERIAL.

By Ensign H. T. Winston, U. S. N., Member.

Compiled from the files of Bureau of Steam Engineering and other sources.

It is intended in this article to show how the best results may be obtained on board U. S. naval vessels with certain material and apparatus; the experience (or lack of experience) of those who care for and operate the machinery, and the general service conditions as they are at present being considered, and the special exceptional cases where some particular arrangement might be satisfactory or perhaps slightly superior being disregarded.

Where there is considerable difference of opinion on any subject, the majority opinion is given.

PIPE AND BONNET JOINT PACKINGS.

High-Pressure Pipe Joints.—For steam pressures over 200 pounds, corrugated, annealed, soft-copper gaskets give best results. The flanges should be male and female, and at least as heavy as the Bureau of Steam Engineering standard (standard sheets Nos. 6, 7 and 9), accurately fitted and grooved; the gaskets and flanges being lightly coated with red lead, care being taken that the quantity used is not sufficient to fill the corrugations and thus destroy their purpose.

For pressures below 200 pounds, less difficulty is experienced in making a tight joint. While the joint mentioned above has certain advantages on account of its lasting qualities, yet on the whole the sheet packings mentioned in the following paragraph have been found more satisfactory.

Whenever the high grade of workmanship necessary for making a copper gasket joint cannot be obtained, where the

flanges are light or old and poorly fitted, where there is considerable vibration, as on torpedo boats, or other causes for not using copper gaskets exist, a waterproof, braided, asbestos sheet packing with wire insertion should be used.

Such packings as Gladiator, Kearsarge and Vulcabeston have given best results.

Water Pockets.—Some trouble has been experienced where steam condenses and water collects at the joint; in such cases a rubber-composition, wire-insertion, sheet gasket may have to be used. Rainbow and brown Garlock have given satisfaction, while in some instances Melville's white oxidized packing has been highly recommended.

A red-lead putty joint with copper or brass wire gauze gives fair satisfaction for pressures below 160 pounds.

Small Branch Pipes.—As these pipes are subject to vibration and jar, flanges as a rule not accurately fitted, bolts not so well spaced and joints frequently broken, copper gaskets should not be used. Asbestos or rubber composition, with wire insertion, will be found more satisfactory.

High-Pressure Bonnet Joints.—For small, well-fitted bonnets plain copper gaskets give satisfaction.

In general, bonnet joints, other than those fitted with copper gaskets, are found most satisfactory when fitted with asbestos sheet material, such as Gladiator and Kearsarge.

Wet joints, however, as those on separators and steam traps, should be made with a high-pressure, wire-insertion, rubber-composition packing, similar to Rainbow, Garlock or Usudurian.

McKim's gasket, King's packing, Klingeret, Melville's white oxidized, Libby's IXL and Common Sense packings have been recommended by some engineers for various bonnet joints.

Low-Pressure Steam and Exhaust Lines (pressures below 50 pounds).—Owing to their durability, copper gaskets should be used where flanges are heavy and well fitted, particularly where the pipes are large and joints inconveniently located for the renewal of gaskets.

A rubber-composition, wire-insertion packing, similar to Rainbow, Garlock or Usudurian, is the best well-known material for joints other than those mentioned above.

A waterproof asbestos-composition, wire-insertion packing will give good results where the joint is fairly free from water.

High-Pressure Fresh-Water Piping.—(Pressures over 175 pounds.)

Bonnets.—For bonnets, joints of feed-water heaters, feed pumps, grease extractors, etc., the following give best results, preference being given in the order shown:

(a) Sheet-rubber composition with wire or cloth insertion, similar to Rainbow, Garlock or IXL.

(b) Soft, corrugated copper gaskets or rings of soft copper wire, where joints are well fitted and not subject to excessive vibration.

(c) Copper or brass wire gauze and red lead, great care being taken in making the joint and in avoiding the presence of lumps in the red-lead putty.

Feed Lines.—For boiler-feed lines preference is given in the order shown below:

(a) Corrugated soft copper gaskets;

(b) Cloth- or wire insertion rubber sheet, such as Rainbow, Garlock or Usudurian;

(c) Waterproof sheet asbestos composition with wire insertion, similar to Gladiator or Kings;

(d) Red lead with copper or brass wire gauze, when carefully fitted.

Melville's white oxidized packing has been highly recommended in this connection by several engineers.

Low-Pressure Fresh-Water Joints—(below 150 pounds).—Any good quality of sheet gum with cloth insertion will give satisfaction. For pressures below 50 pounds the cloth insertion is not necessary.

Low-Pressure Salt-Water Joints.—The packing mentioned in the preceeding paragraph is satisfactory. In renewing these gaskets on board ship, however, it would probably be found desirable to use canvas soaked in linseed oil and

painted with a thick coat of red lead, on account of the cheapness of material, wide-spread use of same for other purposes, and slight deterioration while in store as compared with gum sheet.

NOTES ON RENEWING GASKETS AND FITTING JOINTS WITH SHEET PACKING.

In addition to the preceding, the following suggestions might be added:

When a corrugated copper gasket has been used once it will generally have to be re-annealed and the corrugations reformed in the former before using again, especially in the case of a joint which is likely to leak.

Sheet packing should be chosen as thin as the smoothness of flange surfaces and accuracy of fitting will permit, to prevent likelihood of gasket blowing out; but in case the joint surfaces are not parallel or not properly finished, a very thin gasket would not make a tight joint, and cannot be used.

Ordinary asbestos sheet should never be used for a joint where there is apt to be an accumulation of water or wet steam.

Care must be exercised to see that the gasket is cut properly, no openings being blanked by failure to cut holes in gasket, bolt holes cut so as to give a snug fit around bolts, and that the part which is covered by joint surface is free from cracks or cuts.

Use of Graphite, etc., on Gaskets.—In order that a gasket may be used over again after a joint is broken, and to facilitate the smooth breaking of the joint, graphite and tallow or graphite and cylinder oil should be spread on one or both sides.

Prepared graphite grease is perhaps better for this purpose than an improvised mixture. It would be well to note in this connection that tallow is objected to by some on the ground that the contained acid will attack the gasket material.

In the case of cylinder heads and other bonnet joints which

are frequently broken, red lead should be used on one side of the gasket, as it will then adhere to one of the flanges.

Red lead may be used on both sides of gaskets for cold-water piping, but should not be used for hot water, owing to the difficulty in breaking the joint.

Neither sheet lead nor red lead should be used in lines which carry drinking water.

Wire gauze made from material which will corrode should not be used as an insertion for packing nor with red lead in making a joint.

Preservation of Packings in Store Rooms.—Copper gaskets require little care to prevent deterioration of the material, can be annealed if they harden, and may be corrugated by means of a former which is carried on board ship.

Copper wire, wire gauze, canvas, red lead and linseed oil also suffer little from deterioration.

Asbestos sheet material keeps better than rubber compositions. It should be kept in a cool, dry place to prevent mildewing.

Rubber compositions soon become hard and brittle when stored in a hot, dry place—the usual condition of a ship's storeroom. They should be kept in a cool place, and the stock on hand replenished frequently instead of carrying a large reserve supply.

SELECTION OF PACKINGS FOR NAVAL USE.

It is manifestly an advantage to have as few *different types of packings* as possible on each individual ship and also for the Navy as a whole.

An ideal arrangement would be to make yearly contracts for certain brands which are known to be satisfactory, and to use no other during that year except for experimental purposes, no change to be made until some new packing proves superior to those in use, when that brand should be called for in the next yearly contract. The contractors should be required to furnish the packings to some *central distributing station* (New York Navy Yard, for example), at intervals of three or

four months, or as required by that station; suitable storerooms being provided for preserving packings in good condition, with good facilities for quickly issuing same on approved requisitions. All approved requisitions from ships and stations to be sent to this central station, which would issue fresh, well-preserved packings at frequent intervals for use throughout the Navy. The original outlay would be more than offset by the results obtained and decreased expenditures in the future.

It is believed that not more than four or five varieties need be kept on hand; these to be the ones which have been found most satisfactory in actual service.

It appears that certain packings, like other patented manufactured materials, are likely to be of a poorer quality after the necessary reputation has been made.

FILTERING MATERIAL FOR FILTER TANKS.

Coke put up in bags of coarse toweling, burlap or blanket material gives good results, though the coke disintegrates in time and gets into the feed pumps. With good, strong bags and frequent renewal, this trouble is largely obviated.

Excelsior sewed up in bags of material similar to the above may also be used.

Loofa, the vegetable filtering material, is in high favor with several engineers. It may be put in the filter tank loose or in bags, to suit special conditions.

Marine sponges should never be used as they rapidly disintegrate, are efficient for only a very short time, and are very expensive.

Considerable improvement can undoubtedly be made in the filter tanks at present in use with regard to efficiency and facility for overhaul, cleaning and renewal of filtering material.

Special care should be exercised that the filter chambers of tanks are easily accessible, and, when possible, the cover should be fitted with hinged bolts to facilitate removal.

It is important that filter tanks be cleansed frequently and the filtering material renewed when necessary; once a month

will probably be found often enough under ordinary service conditions.

Drain pipes of every description should discharge into the filter tank, in order that all water taken from the feed tanks by the pumps will have been filtered.

Grease Extractors.—The following is from a circular recently issued by the Bureau of Steam Engineering:

Grease extractors, in addition to the separate filter tank, are in general to be fitted on all vessels building and on vessels undergoing general overhauling, where circumstances make it desirable and where suitable space and arrangement for their installation may be obtained.

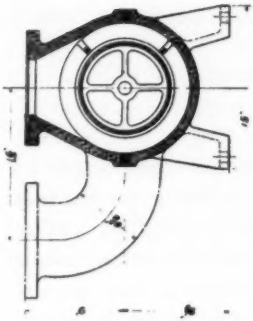
Grease extractors will be located, in general, on the discharge side of the main feed pump, between pump and feed heater, or, in vessels where hot-well pumps are fitted, on the discharge side of hot-well pumps. The location must be such that all parts are accessible for overhauling and cleaning. Especial attention must be given to the details, so that bonnets and filter cartridges can be readily removed and the cartridge eased off its seat by mechanical means.

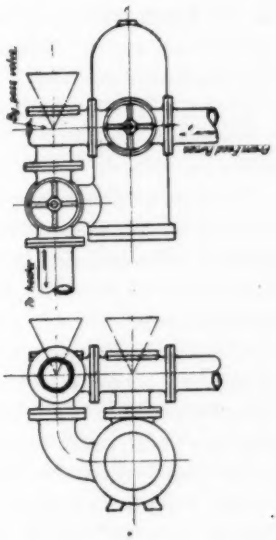
Grease extractors will be of the cartridge type, similar in principle to those shown on Bureau Steam Engineering plan No. 8, S, 1, on opposite page. They are to be fitted with by-pass valves.

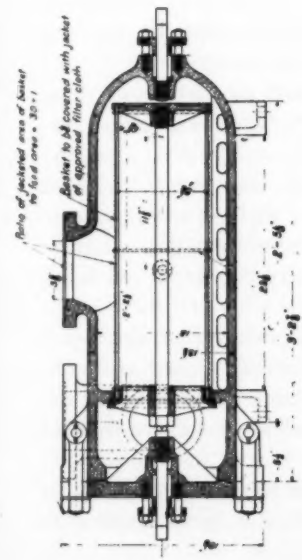
The cartridge should be lined with coarse, heavy toweling or linen filtering cloth, and suitable spare filter jackets will be supplied. The surface of filtering jackets should be as follows: Ratio of area of filter jacket to area of feed pipe, not less than 30. The perforations of filter basket must be at least 50 per cent. of its total area.

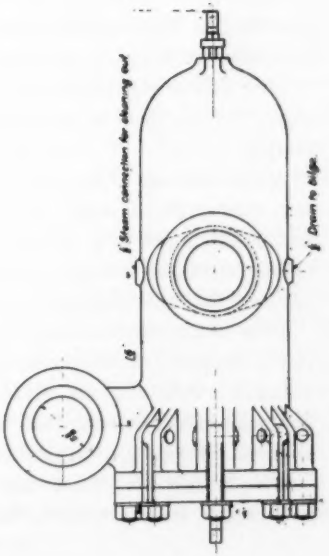
Grease extractors will have a drain cock and a ½-inch steam connection for boiling out, a plug for introducing soda, and an air cock.

Grease extractors should have their filtering material renewed at least once every two weeks, if found necessary, and more frequently if a considerable quantity of grease and oil collects. They should be drained of oil, by-passed, and blown









out by steam daily while steaming and twice weekly when in port, if necessary. Except when under repairs, they will be kept in continual use.

STEAM TRAPS.

TYPES OF TRAPS.

The *open-bucket float type*, though bulky and somewhat affected by the ship's motion in a sea way, has given the most general satisfaction. It will take care of a sudden gush of water and requires no adjustment for varying pressures and temperatures.

The *hollow-ball float type* has given some trouble on account of the ball corroding through, getting punctured or becoming detached. This type should give satisfaction if proper provision has been made to insure watertightness of the float and if the float is securely attached to its lever.

The *expansion type* of trap is superior to the float type in that it is not bulky, has few parts and lasts well. It does not work well where there are wide variations in the temperature or amount of water to be handled. Under such conditions trouble has been experienced with the frequent adjustments, irregular working of trap and leakage of steam.

The following traps are largely used in the Navy: (float type) Dinkel, Nason, McKellar and Kieley; (expansion type) Geipel.

Requirements of a Good Trap.—The best trap is one that will discharge the water which collects without wasting steam and at the same time requires little attention. Other qualities to be considered are durability, simplicity, facility of overhauling, weight, size and cost.

It is better to have the drain valve of a trap at the top of the chamber rather than at the bottom, where sediment collects. It is also an advantage to have valves outside the float chamber, where they may be cleaned and overhauled without breaking a large joint.

The bonnet of a float trap should be secured with studs, or if through bolts are used, the heads should be so fitted as to

prevent turning. The facility for overhauling might be still further increased by the use of hinged bolts.

The piping for all traps should be fitted with union couplings to facilitate the removal of trap for examination or repair. In the case of an expansion trap, the discharge should be fitted with a by-pass to the bilge by means of which it could be determined whether the trap was working properly.

Traps for Special Uses.—Where the quantity of water is subject to sudden variations, as in steam-pipe and separator drains, the float type should be used. Where there is a slow, regular and continuous condensation at a practically constant temperature, the expansion type is satisfactory and often desirable.

For *cylinder jackets* of main engines an arrangement similar to that on vessels of recent designs seems best; *i. e.*, steam goes from the H.P. jacket to the I.P. jacket through a reducing valve, from the I.P. jacket to the L.P. jacket through another reducing valve, and then drains through the L.P. jacket trap; one trap taking care of the water for the whole system.

The following easily improvised substitute for a jacket trap has been used with success: A small cast cylinder, fitted with a drain valve and gauge glass, is placed in the jacket drain-pipe line. When in operation the drain valve is opened just enough to keep the water in gauge glass at a fixed height, the whole arrangement being near the starting platform, and readily seen.

For *steam radiators* the bucket type generally gives best results. Expansion traps when used should be placed close to the radiators, and each trap should not drain more than two or three coils; they have been found to give considerable trouble when required to drain more than one heating circuit.

For *evaporators and feed heaters* bucket traps have been extensively used. It is probable that an expansion trap, carefully installed, would work efficiently on evaporator coils.

Drains for feed-water heaters when discharging to condensers do not require traps, but if the heater drains discharge to feed tanks traps may be necessary.

For *steam separators and steam lines* the bucket type must be used.

LOCATION OF TRAPS.

A trap must be located below the lowest part of the vessel or pipe to be drained, and, if practicable, above the level of the tank into which it discharges, in order to prevent water backing up when the trap is not in operation. This applies particularly in the case of the expansion trap, which has given trouble in discharging against a head of water. Under certain conditions it may be necessary to fit a non-return valve in the discharge line.

All traps, and particularly those which will need frequent overhauling, should be so placed as to be easily overhauled and examined. If a trap cannot be installed where it is fairly accessible for overhauling it should be omitted and a drain valve fitted instead.

OPERATION AND OVERHAULING.

Many traps are of no value on account of lack of care and attention.

A float trap can be heard "dumping" when in order, and may work satisfactorily for months without overhauling. Whenever the sound of dumping is not heard at intervals the trap should be examined at once. Less trouble is experienced with a large trap than a small one, as in the latter case valves are more easily clogged, thus causing a failure to discharge, or if not entirely stopped will permit a leakage of steam. This is paritcularly the case where there is likely to be sediment in the water.

While experience is necessary to judge in each particular case the period a trap may be left without examination, it may be said in general that a large trap should never go more than three months nor a small trap more than two months without examination and cleaning.

By opening the expansion-trap discharge by-pass to bilge it may be seen whether the trap discharges water properly, and if it leaks steam. The trap should be tested frequently when in use and adjusted or cleaned out if necessary.

THE FUTURE OF MARINE GAS ENGINES.

By Peter Evermann, Associate.

In presenting this paper to a society interested in marine engines it is hoped that it may have the effect of attracting more attention to the gas engine, especially in so far as it relates to its possible substitution for the old and reliable reversible steam engine on board ship.

During the past century the progress of science and industry was marked by the ingenious development of the steam engine and boiler, and in the present one by the remarkable improvements already made in the gas engine.

As in a large measure all modern transportation facilities were developed along with the steam engine, may we not look for a similar advance as the gas engine and producer are perfected?

It will be noted that the principle is not a new one, it having been first brought forth about the year 1860, based upon the experiments of the French engineer Lenoir. His engine was, however, not sufficiently economical for commercial purposes.

The next step of importance in this connection was made in the Otto engine, brought out in Germany in 1882. The name of Lenoir will always be associated with the so-called "two-cycle" principle and double-acting engine, while that of Otto will be remembered in connection with the "four-cycle" principle and single-acting type. Both systems are so well known that any description of them would seem unnecessary. The main features will, however, be set forth in a few words.

Figure 1 (not in proper proportion) is the diagram for a four-cycle engine. Line I represents the suction stroke of the piston, during the whole of which the explosive mixture is being drawn into the cylinder; II is the second or compression

stroke. III indicates the explosion which takes place at the beginning of the expansion stroke, IIIa, which is similar to the corresponding stroke in a steam engine. Before the end of this stroke is reached the cylinder begins to open to exhaust, as indicated at IIIb, and the whole of the following one, IV, is spent in expelling the products of combustion.

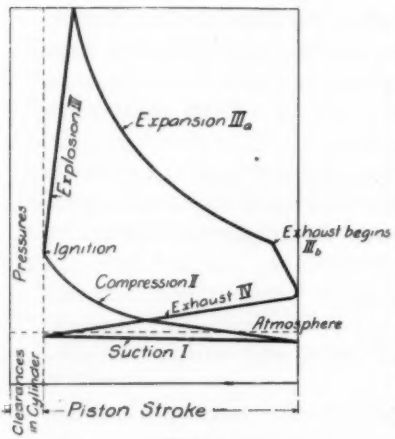


Fig. 1.

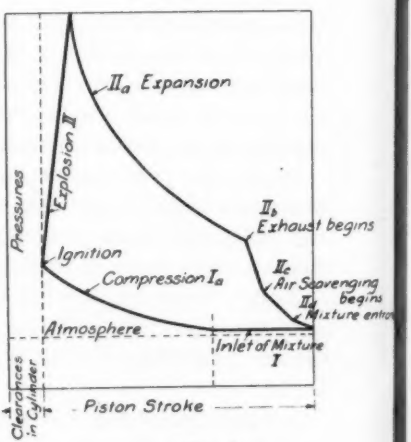


Fig. 2.

The various machines to be found on the market differ very little in so far as the principle of burning the gases is concerned, and little difference will be noted in the various diagrams. The main point of difference is in the crank angles, but a variation of ten or fifteen degrees one way or the other at the dead point of the piston will not be very noticeable on the diagram.

Fig. 2 represents the diagram for a two-cycle engine, and shows very clearly the difference between the two strokes of this type as compared with the four strokes shown on figure 1. During the first stroke the explosive mixture is forced into the cylinder (I) and compressed (Ia), while during the next, five operations are performed: these are: the explosion (II), followed by the expansion (IIa), the exhaust (IIb), the

scavenging of the cylinder (IIc), and the admission of the fresh charge (IId).

It will be noted that in the case of figure 1 there are three lines below the atmosphere, from which it will be seen that the four-cycle engine is capable of sucking the explosive mixture into the cylinder, and may thus be made to produce gas from its own power. In figure 2 there are no lines below the atmosphere, from which it follows that some auxiliary power must be utilized for supplying gas and forcing it into the cylinder. These facts might show why, under certain circumstances, one type is to be preferred to the other. In connection with this much discussed question I would suggest that, as a general rule under ordinary circumstances, the two-cycle type be adopted where the gas is produced under pressure, and naturally the four-cycle type where the gas is to be produced by suction.

The use of explosion engines in small boats is so well known that little need be said concerning them. Up to the present time the only successful fuels for these engines have been of a liquid character, such as gasoline, kerosene and alcohol, though tests have been made with illuminating and other gases stored in tanks under a high pressure.

The use of gas producers for boats has, I believe, received attention since the earliest days of gas-engine building, but there have not been any very important developments along this line, and large gas engines for this purpose have not as yet been built. It appears that one of the principal reasons why the gas engine has not come into more general use is the uncertainty as to the question of reversibility. It has been held that engines of this type having a capacity of more than 100 H.P. are impracticable, it having been shown that, as compared with the ordinary steam engine, they are subject to much greater vibration, have much more weight in themselves, besides the heavy flywheel and gearing, and that the valve and igniter motions are of a complicated character. Owing to a lack of positive connection between the main engine and propeller shafting, it has been considered doubtful whether large

gas engines would ever be available for use on board ships of the Navy.

The development of the large engine using a very poor lean gas has been such that I believe the builders of marine engines will be forced to take up this type, as was the case in stationary practice.

So far as I can recall there is not a large company in Europe, having a reputation for high-grade steam engines, which has not been forced to put on the market some type of internal-combustion engine.

So much has been written of late concerning the rapid development of this type of motor that I will not dwell upon that point, but would mention the fact that the improvement in the large types has been followed by a corresponding development of the producer, just as in the case of the steam engine where the increasing efficiency demanded better boiler and condensing plants. The best type of gas engine would have no sale if it were not possible to supply a cheap gas of good quality for its operation. The construction of large engines operating with blast-furnace gas having a calorific value of not more than 90 to 100 B.T.U.s has led to the development of another type to use producer gas whose value in B.T.U.s varies from about 125 to 170.

Fig. 3.

Kind of Gas.	H.	CH_4.	CO.	CO_2.	N.	Combustible parts.	Air required.	B. T. U.
Natural	2.	93.8	0.6	0.6	3.	96.4	8—9	1,100
Illuminating	46.	45.	7.5	1.	0.5	98.5	6—7	700
Coke oven	60.	22.	10.6	3.	4.4	92.5	4—5	450
Water	50.	6.	35.5	3.5	5.	91.5	3—4	350
Producer, bituminous coal	18.	3.	20.	4.	55.	41.	2.	160
anthracite coal	12.	1.	26.	5.	56.	39.	1.5	140
coke	3.	0.6	25.	6.	65.4	28.6	1.	120
Blast-furnace	2.	1.	24.	7.	63.	27.	0.9	100

Fig. 3 gives the composition of the above as compared with the rich natural and illuminating gases. This table substan-

tiates the theory and is in keeping with the result of actual practice, where it has been found that the amount of air required for combustion increases with the quantity of combustible gases, and especially with the amount of heavy hydrocarbons in the mixture, and explains why poor gases have been found to give very nearly as much horsepower as stronger ones in cylinders of the same size.

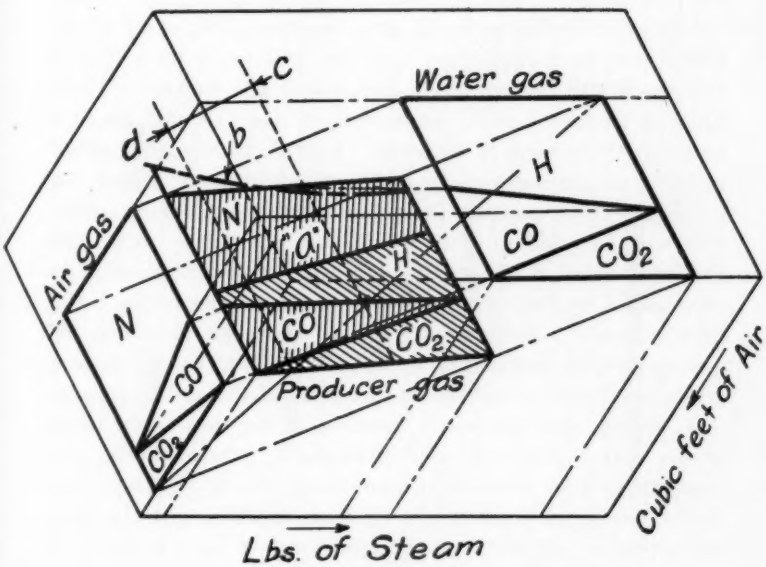


Fig. 4.

It has been demonstrated by special tests as well as in actual practice that, in the case of water-cooled engines, the more nearly instantaneous the combustion the better will be the efficiency obtained. Hydrogen being a highly-inflammable and quick-burning gas, is of assistance in this connection. The presence of a certain percentage of free hydrogen is also desirable to insure the proper action of the igniting spark.

Mr. K. Kutzbach, a German engineer, has recently published a very interesting paper in which he shows the influence

of steam or vaporized water in gas producers, as follows: A diagram, the one at the left in figure 4 illustrates the gasifying of carbon with air. The one at the right is a similar diagram, in which steam is used. By connecting the two we obtain a third, a, showing the composition of ordinary producer gas It will be seen that producer gas consists, essentially, of nitrogen, hydrogen, carbon monoxide, and carbonic acid, and that the percentage of each is dependent upon the others.

The more hydrogen in the gas, the more carbon will be required for its manufacture and the more expensive it will be; but it will be seen from line b that the number of heat units is increased with the increase of the CO, and hence a better quality of gas is obtained. As stated above, the inflammability is increased by the addition of hydrogen; hence, for good gas-engine practice, the object should be to obtain a mixture with just enough hydrogen to insure ignition. With the producer a gas, is generally obtained whose composition is represented by that portion of the diagram lying between the lines c and d. Blast-furnace gas is nearly an ideal one for gas engines, its composition being principally CO and nitrogen, while water gas is composed principally of CO and hydrogen.

Touching now upon the question of economy, which together with that of a reduction of the number of parts is of most importance on board a man-of-war, it will be noted that in the case of engines operating with producer gas, the consumption has already been brought down to $\frac{8}{10}$ of a pound of coal per I.H.P. per hour, which is less than one-half that required for the best steam-engine installations.

As to the steam turbine, which is in much favor just at present, I might add that this type will always require more steam than a good reciprocating steam engine, and it is also a question whether it will be found satisfactory for use at sea in heavy weather. In my opinion it will never come into serious competition with the reciprocating steam or gas engine. The gas turbine might, however, be more highly recommended, as its character is such as to permit of construction in lengths more suitable for marine practice than its steam competitor.

Figure 5, which represents an average diagram for a non-condensing steam engine, shows an efficiency of $7\frac{1}{2}$ per cent. obtained from the coal in an ideal frictionless machine.

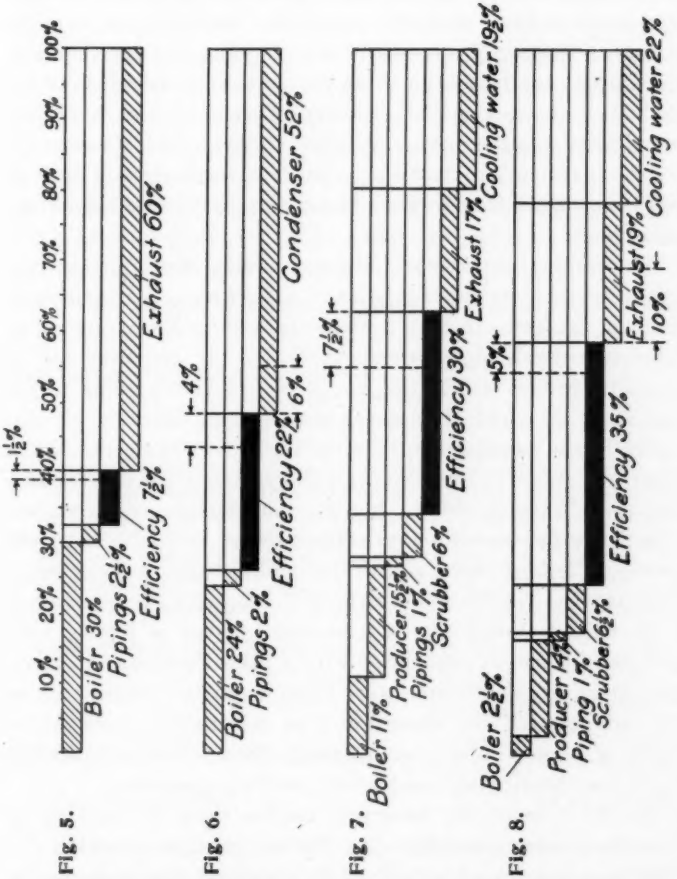


Fig. 5. Fig. 6. Fig. 7. Fig. 8.

Assuming a mechanical efficiency of 80 per cent., this amount is reduced to 6 per cent. The loss in an ordinary boiler may be taken as 30 per cent., with a further loss of $2\frac{1}{2}$ per cent. in the piping and 60 per cent. in the exhaust, thus making the

old type of engine a very uneconomical machine. By the selection of a better type of boiler, the use of heaters for the feed water and superheaters for the steam, the boiler loss may be reduced to about 24 per cent., as shown in figure 6, which represents a good modern condensing steam engine, having a loss of 52 per cent. in the exhaust. For this type the efficiency may reach as high as 22 per cent., from which must be deducted about 4 per cent. for mechanical losses, leaving a maximum efficiency of 18 per cent., a figure which has never yet been reached in marine practice, as the reversible type of engine required for this work can not equal the best stationary machines.

For comparison with the above, a similar diagram, figure 7, is given for a "pressure-producer" gas plant. As is generally known, the losses in such a plant are principally in the boiler used to furnish high-pressure steam for the producer and in the scrubber, in which the gas is cooled before going to the holder, from which it passes to the engine. The loss of heat units in the auxiliary boiler is as high as 11 per cent., in the producer about 15½ per cent., in the piping 1 per cent., and 6 per cent. in the scrubber. In a good, modern two-cycle engine there may be carried away in the exhaust as much as 17 per cent. of the heat units, and in the cooling water 19½ per cent., thus leaving for the plant a thermal efficiency of 30 per cent.

It will be noted that a four-cycle engine is just as well adapted for use in connection with a pressure-producer plant; but, from my experience with these engines, I would advise the adoption of the two-cycle type for marine purposes, in spite of a possible higher thermal efficiency to be obtained from the other, when used with a suction producer.

In the case of the two-cycle engine there is required an auxiliary compressor plant for the air and gas in which the efficiency loss amounts to about 7½ per cent., thus bringing the total efficiency down to 22½ per cent., as shown in figure 7.

Figure 8 is a diagram showing the distribution of thermal units in a modern stationary suction-producer plant of large size. In this case steam of high pressure is not used, but

there is a vaporizer in which the loss amounts to 2½ per cent.; the loss in the producer is reduced slightly, amounting to 14 per cent., as compared with 15½ per cent. in the pressure type. With a loss of 7½ per cent. in the piping and scrubber, 19 per cent. in the exhaust and 22 per cent. in the cooling water, there still remains 35 per cent. of the calorific value of the fuel for the engine; allowing 5 per cent. loss for the engine, we have a brake horse-power efficiency of 30 per cent. In my opinion these figures are such as to warrant the building of marine gas engines.

The following calculation shows the heat-balance scheme for a pressure-producer plant using fuel with a thermal efficiency of approximately 13,100 B.T.U.s:

Coal charged per hour in producer, pounds	225
boiler, pounds	25
total, pounds	250
Total heat units charged in plant per hour	3,275,000
boiler per hour	327,500
furnished by steam per hour	181,600
lost in boiler per hour	145,900
charged in producer per hour	2,947,500
added to producer by steam	181,600
in producer	3,129,100
The gas obtained from the 225 pounds of fuel was approximately 17,000 cubic feet, with a calorific value of 150 B.T.U.'s, thus giving in heat units	2,550,000
Loss in producer was thus	579,100

The efficiency loss in the producer was, then,

$$\frac{579{,}100}{3{,}275{,}000} = 17.8 \text{ pr. ct.}$$

$$\text{The efficiency loss of the boiler} = \frac{579{,}100}{3{,}275{,}000} = 4.5 \text{ pr. ct.}$$

Total loss in plant, ... = 22.3 pr. ct.

This may also be arrived at in the following manner: There was obtained per pound of fuel in the producer 75.6 cubic feet of gas, or in the plant, 68 cubic feet, having a calorific value of 150 B.T.U.s, thus giving approximately 10,200 B.T.U.s, whereas the value of the fuel was 13,100 B.T.U.s, which shows a loss of about 22.2 per cent.

For gas with a value of 140 B.T.U.s the efficiency is 72.6 per cent. as compared with 77.8 in the above case.

From figures 5 to 8 it will be seen that there is no very great difference between a good boiler plant and a good producer plant. The gas engine, however, should be preferred not only on account of its superior economy but for the reason that it is safer, as in this case we do away with a system of piping carrying steam of a very high and dangerous pressure. The supply of coal is easier in the case of the producer than in that

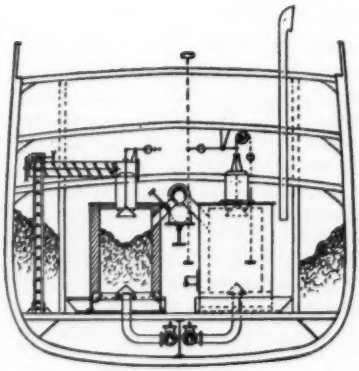


Fig. 9.

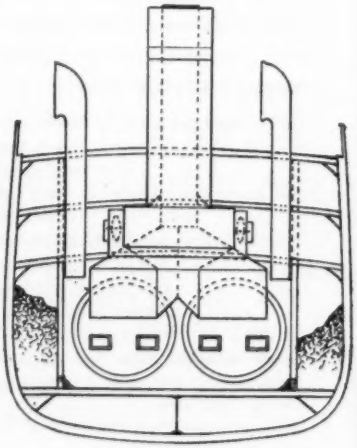


Fig. 10.

of the boiler and, as will be seen by comparing figures 9 and 10, the form of producer is such that it can be installed on board ship without greater difficulty.

In figure 11 is shown the general arrangement proposed for the engine room.

(Some further points as to the installation of large gas engines in the case of railroad locomotives will be found in an article by the writer which appeared in the "Scientific American" of February 4, 1905.)

In connection with existing installations of small internal-combustion engines I would call your attention to figures 12

and 13, showing the plan and elevation of a Fairbanks-Morse 2-H.P. gasoline engine for a launch, the details of which will be seen in figures 14 to 16. It is of the two-cycle type, and has the advantage of no valves on the cylinders, a feature which is of such importance that I would propose to accept this general principle for engines of the largest type. There is only one automatic valve for the air suction.

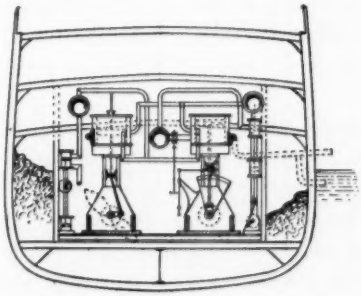


Fig. 11.

That the reversing shaft may be avoided has been demonstrated in the engines built by the Standard Motor Company and others. A reverse motion may be obtained by advancing the point of ignition so as to give an early back pressure on the piston in the proper direction; by shifting the valve motion; by the use of an auxiliary air compressor plant; or by the proper distribution of the explosives in the various cylinders.

In connection with the small engine just referred to, it may be of interest to examine the cylinder details as shown in figure 17. The exhaust opening is located near the lower end, with the mixture inlet a little higher up, at a; the piston in its lower position, b, opens the exhaust as well as the inlet, thus scavenging the cylinder and at the same time filling it. This type is very satisfactory even though not so economical as larger engines working on the four-cycle principle, but the latter are more or less complicated owing to the various valves and the mechanism necessary to operate them.

Fig. 12.

1. Cylinder.
2. Cylinder Head.
3. Heater.
4. Throttle Valve.
5. Float Reservoir.
6. Oil Valve.
7. Circulating Pump.
8. Sea Cock.
9. Reversing Gear.
10. Coupling.
11. Exhaust Pot.
12. Exhaust Muffler.
13. Exhaust Elbow.
14. Oil Tank.
15. Oil Feed Pipe.
16. Lubricator.
17. Electric Igniter.
18. Battery.
19. Switch.
20. Spark Coil.
21. Inboard Stuffing Box.
22. Outboard Stern Bearing.
23. Propeller Wheel.

Fig. 13.

It may be asked why, in view of the greater economy of the four-cycle engine, I should propose the two-cycle type for use on board ship. It is because the production of *poor* gasses can be easily carried out in modern producers and these gases are suitable for this type of engine, while gasoline and such fuels are too expensive for use; and then, in order to save weight, the engines will necessarily have to be made double acting. The gas under pressure is obtained from the producer direct, and the air required for scavenging may be compressed to the few pounds required by any convenient auxiliary apparatus.

Figure 18 shows the framing, drawn to scale, for a 10,000-H.P. engine, from which it will be seen that the lower part may be open, as in the case of a steam engine, and the cross-heads, crank pins, piston and rod-cooling devices, main bearings, etc., will be easily accessible. It will be noted that this engine is of the same size as a steam engine of corresponding power, its height being 36 feet and length 34 feet.

A proposed method of constructing the large cylinders for such high-pressures is shown by figure 19. A good proportion would be cylinder diameter, 60 to 70 inches, and stroke, 72 inches. The exact diameter of cylinders would depend, of course, upon the quality of the gas to be used. With eighty revolutions per minute this would give a piston speed of 960 feet. It should be remarked that for a steam engine of this same power there would be required a low-pressure cylinder with a diameter of 112 inches. There is, however, one point which might at first appear to place the gas engine at a great disadvantage; it is the enormous pressure brought to bear on the crank pins and main bearings by the force of the explosions. With a piston area between 2,827 and 4,071 square inches, and a pressure of 400 to 450 pounds per square inch, the resulting pressure on the bearings would be between 580 and 700 tons.

With a plentiful supply of water, which may be obtained from the sea, trouble from this source can be avoided. It will not be necessary to provide fresh or filtered water for cooling

purposes, sea water being used, provided proper arrangements are made for cleaning out the various passages.

The next question of importance is to get rid of the heavy

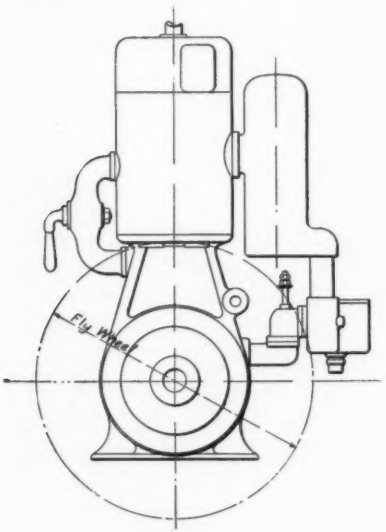


Fig. 14.

cylinders. If made of cast iron its thickness would have to be about 4½ or 5 inches, and for cast steel 2½ to 3 inches. There can be obtained from existing mills seamless-rolled cylinders, with diameters of 6 feet and over, in lengths of 10 feet. It is such cylinders, of nickel-steel, that I would propose to use for the large engines. Even if it should be found necessary to make them in two sections, the thickness in such cases would not be more than 1½ to 2 inches.

From figure 19 it will be seen that the openings for inlet and exhaust come at the end of the stroke, when the pressure in the cylinder is very low, being not more than about 60 pounds, so that no trouble need be experienced with the connections at these points. The cylinder heads may be tied together by rods, as in the case of an hydraulic press.

By using specially operated gas valves, as shown by the dotted lines in figure 19, it would be possible to employ air

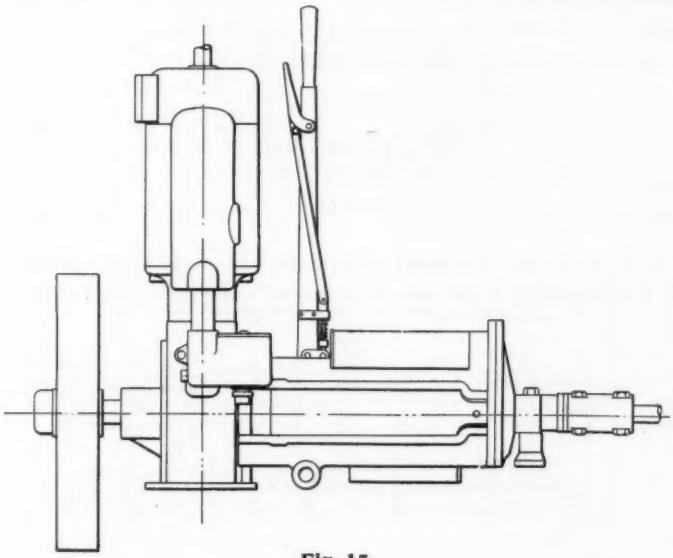


Fig. 15.

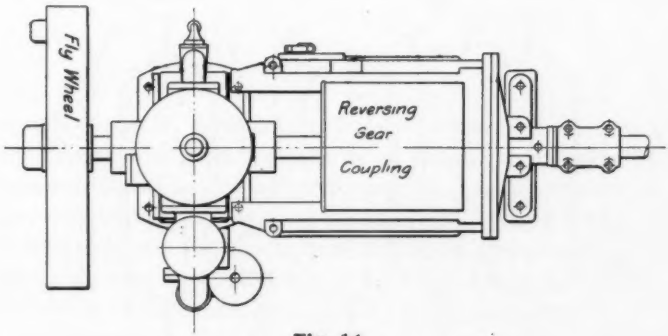


Fig. 16.

alone for scavenging and thus effect a saving in fuel.

The gas engine itself will be found heavier than a steam

engine of the same power, but as the condensers with their fittings will not be required the final result may be an actual saving in weight.

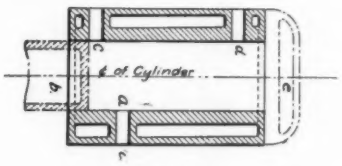


Fig. 17.

A note might be added concerning the rapid development of the so-called "waste-heat engines." It has been demon-

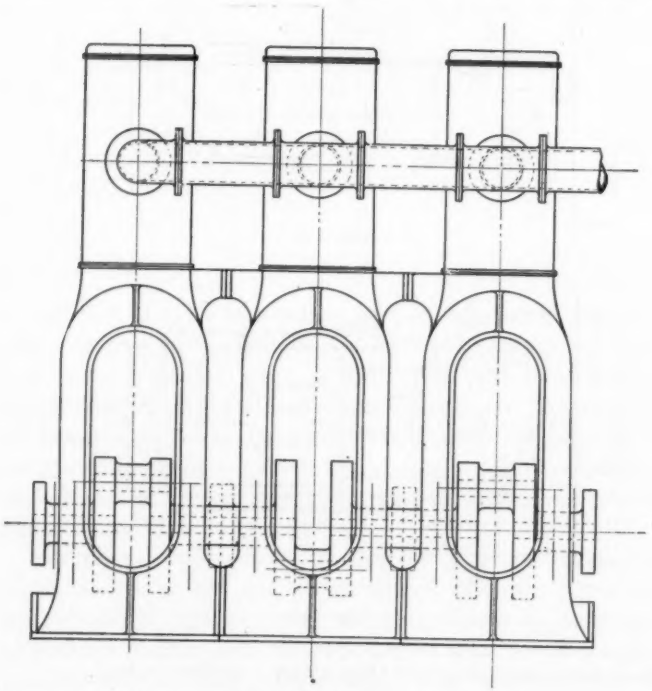


Fig. 18.

strated that a saving of 6 per cent. may be obtained in the case of large condensing steam plants, as indicated on figure 6, and it is expected that in the case of gas engines this will amount to as much as 10 per cent. (see figure 8), the waste heat being utilized for the electrical operation of the auxiliary machinery, for heating the vessel and other similar purposes.

In a steam engine installation of 10,000 H.P. it is probable that there would be installed five boilers, each with a capacity of 2,000-H.P., which, in the case of cylindrical boilers, would weigh, including water, smokepipes and fittings, about 220

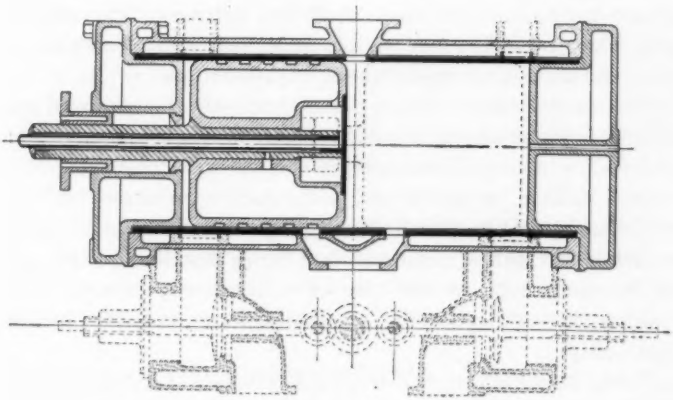


Fig. 19.

pounds per H.P.; though in the case of certain types, such as that invented by Professor Schutte, of Danzig, this weight has been reduced to 150 pounds. Taking 200 pounds as an average, there would then be for a steam plant a total of 2,000,000 pounds, or 1,000 short tons, in addition to the engine weights. The grate area would amount to about 750 square feet and the floor space required would be about 1,500 square feet.

For a producer plant it is safe to count on 10 square inches of grate per H.P., though this may, in large installations, be reduced to 8 square inches or even less, thus giving a total of 700 square feet. For a continuous supply of gas of a good

quality it would be advisable to divide the plant into a number of small units. I would propose that ten producers, each with a capacity of 1,000 H.P. and 70 square feet of grate area, be adopted. The inside diameter of each would then be about 10 feet, which would correspond to an outside diameter of 12 feet, and would require for the whole plant a floor space of 1,140 square feet, as compared with 1,500 in the case of the boilers.

As to the question of weight, this is also in favor of the producers; each would weigh about 125,000 pounds, of which amount 77,000 pounds would be in fire-brick, and the remainder, 48,000 pounds, in the steel shell and fittings. This would give a weight of 125 pounds per H.P., or a total of 625 short tons, and show a saving of about 375 short tons.

For the operation of the plant there will be required no skilled fireman and a smaller number of engineers, and the probability of serious accidents will have been lessened.

In a system for which the writer has secured patents the scrubber, heretofore attached to each producer, has been omitted, only one central cleaning plant being installed and no gas holder used, even in the case of a pressure producer, thus making the installation one particularly well suited for use on board ship.

Every naval officer will readily appreciate the great advantage to be obtained by avoiding the use of smoke pipes, and thus reducing the chances of the vessel being discovered at great distances by the clouds of smoke, as at present.

For vessels of the Navy the space and weight saved may be utilized for an increase in the armor and armament or for additional coal supply. With the same coal capacity as heretofore, the saving of about one-third in the coal consumption will give a much greater steaming radius.

There will be no competition between this type of installation and one using a liquid fuel, as the latter is too expensive as well as dangerous for use on shipboard.

FUEL FOR SHIPS OF WAR.

ITS ENGINEERING AND MILITARY RELATIONS.

By Lieutenant H. C. Dinger, U. S. N., Member.

The comparative efficiency of vessels of war, the offensive and defensive qualities being equal, will depend upon the endurance and steaming radius.

The endurance will depend upon the reliability and durability of the machinery, which qualities are obtained in the highest degree by proper design, careful arrangement and installation, the use of good material and workmanship, and last, but not least, proper care and management.

The steaming radius will depend upon, 1. Bunker capacity; 2. Quality of fuel; 3. Efficiency of devices used for converting the energy of the fuel into that of the steam; 4. Efficiency of the machinery for converting the energy of the steam into propulsive effect.

COAL BUNKERS.

The bunker capacity is determined by the space available. To be efficient it must provide facility for stowing and completely filling all bunker space, and means for readily getting the coal to the furnaces.

Facility for stowing.—The primary object in carrying coal is for use as fuel in the boiler furnaces. This fact should not be lost sight of in arranging the coal bunkers of a naval vessel. From numerous examples in existence an uninitiated observer might be led to believe that fuel-carrying ability was the last thing considered in the design and arrangement of the bunkers.

It is true that coal protection has a certain amount of military value, but the knowledge of this fact should not lead us

into dangerous paths. The idea of coal protection has led to grave errors; one of which is the designing of coal bunkers so that the coal, when once stowed, is placed in a position well adapted for protection; but, owing to their inaccessibility, the bunkers are practically useless for carrying fuel for the boilers. The bad effect of trying to use coal for protection manifests itself in having bunkers fitted in narrow and irregular spaces or in small pockets from which the fuel can neither be taken to the fires nor stowed from deck except with great difficulty.

Fuel is being constantly consumed, and there is thus present the liability of the bunkers being empty when the protection is needed. Protection by fuel is thus in any case an uncertain and indefinite quantity upon which dependence can not be placed.

The primary purpose of coal on board a vessel should be to generate power, and the primary idea in the arrangement of coal bunkers must be that of readily getting the coal to the bunkers and from the bunkers to the furnaces in the easiest possible way. To this end the major portion of the coal should be in large bunkers, which are close to and have the shortest and most direct communication with the fire room.

Bunkers should be few in number and of large capacity rather than great in number and of limited capacity. With fewer bunkers the number of chutes, scuttles, doors, etc., is very much less, thus avoiding considerable weight and complication. Large bunkers are also more easily stowed, while with small ones this is very difficult.

The only limitation placed upon the size of bunkers on board men-of-war should be such that the flooding of any one would not heel the vessel to a dangerous degree. Necessary strength can be obtained by fitting stanchions, stringers, beams, etc.

INTERNAL ARRANGEMENTS OF BUNKERS.

To facilitate stowing there should be provided: A sufficient number of *chutes* as large as the structural limitations will allow, located so that the coal will most easily distribute itself

to all parts of the bunker. Such chutes should lead direct to the bunkers without intermediate passageways, twists or turns.

Proper *escape doors*, so located with reference to the chutes that the least amount of vacant space is left in bunker, yet still providing a means of escape for the trimmer.

Proper *ventilation*, in order that the coal trimmers may not be required to work in excessive discomfort.

To facilitate the taking of coal from the bunkers there should be—

Platforms from which the coal can be shoveled.

Trolleys and *switches* for transporting coal buckets from distant points.

Doors, *scuttles*, *hatches*, etc., must be so designed as to be easily opened and closed and to withstand rough handling.

EMPLOYMENT OF MECHANICAL MEANS.

Mechanical means for bringing coal from bunkers are in all probability not applicable to the conditions on board ship, chiefly on account of the weight and the space necessary for their installation: the space required for such installation being an encroachment upon the bunker capacity.

If mechanical appliances can be devised to do such work, which weigh less and occupy less space than men doing the same work, then there may be some reason for such an installation; at present no such devices are in sight.

QUALITY OF FUEL.

A first impression might give the idea that the fuel which contains the greatest number of heat units per unit of weight would be the most desirable. This is, however, not necessarily true. Other things must be considered, among which are:

1. Safety.
2. Facility for handling and stowing.
3. Facility and ease with which combustion can be obtained and maintained.
4. Maximum evaporative result that can be obtained with a unit weight of boiler of a type suitable for marine installation.

5. Availability and facility of supply.

If these items are considered with regard to oil fuel, items 1 and 5 are of smaller value than with coal. Item 2, however, is much greater with oil.

Liquid Fuel.—The advantage of the use of liquid fuel, aside from all question of adequate supply or cost, may then be determined by properly considering its bearing on the above items.

Kinds of Coal.—Items 1 and 2 are practically alike for nearly all kinds of coal. Anthracite coal offers more advantage by reason of closer and cleaner stowage.

Under item 3, "Facility with which combustion can be obtained and maintained," the kind and character of the coal should become a matter of thorough consideration.

Coals are relatively efficient as follows:

(a) In as far as they show a small percentage of ash.

(b) In that they do not clinker.

(c) In that they are not likely to produce a secondary combustion.

(d) In that they are not ground to powder, which will allow large quantities of fuel to drop through the grate.

Item 4 is one that very often may not be carefully considered. Other things being equal, that fuel is best from which a certain evaporative result per unit weight can be obtained with the least weight of boiler. Fuel that would require added weight to the boiler installation in the way of special furnaces or other appliances will thus have a severe handicap.

AVAILABILITY OF SUPPLY.

Any fuel for naval vessels must, in general, have an available supply throughout the probable seat of operations for the vessel; otherwise her field of action is limited. Naval vessels, in general, must have the whole world for their field, and until a proper available supply of any particular fuel can be assured in all portions of the globe, such special fuel can not be advantageously used for naval purposes. With merchant vessels plying in a definite locality or on a definite run

this is altogether a different question. For such naval vessels whose sphere of action is confined to a particular locality, fuels available in that locality and which have special advantages ought to be used.

Efficiency of conversion of the heat of fuel into steam will depend upon the following points:

Firing.—This at once brings up the question of hand firing or mechanical firing. Mechanical firing is successful on shore, but on board ship its limitations are such, especially on a man-of-war, that the probability of this means being used for burning coal is yet far distant.

The disadvantages are:

(a) *Weight.*—The added weight is much more than the weight of the additional men required for hand firing.

(b) *Space.*—The space required is more than that necessary for hand firing.

(c) *Adjustment for raising speed by increasing rate of combustion.*—This is very difficult, practically, with any mechanical system. Mechanical stokers do not work successfully at any where near the rate of combustion of 50 pounds per square foot of grate, this being the rate often necessary on account of limitations of space.

(d) *Complication entailed.*—The fittings of the mechanical stokers require considerable care and attention.

Hand firing.—Matters that will affect the efficiency of hand firing are:

(a) *Length of grate.*—Grates should not be over 6 feet 6 inches long; a longer grate cannot be properly fired for more than a short period. Attempts at firing long grates result in making the rear of grate inefficient, since this part cannot be thoroughly cleaned, nor can the fuel be properly broken up.

(b) *Height of fire-doors and the general ease with which they can be handled, slope of grate, etc., and its relation to direction of passage of gases.*—Each of these matters, if not properly designed to meet attending conditions, will detract from efficient firing.

(c) *Depth of fire room.*—The depth must be such that slice

bars can be handled with ease. The space in wake of furnaces must be absolutely clear, so that firemen run no danger of striking their hands against stanchions, ladders, etc.

(d) *Ventilation and temperature of fire rooms.*—The fire room for natural draft should provide a good supply of fresh air and ample means of escape for the heated air. For forced draft, discharges should be led so that the air is not likely to stir up coal dust.

(e) *Skill of firemen and system of firing employed.*—This, of course, is a feature of overwhelming importance. Another matter affecting the firing is the amount of ashes and arrangements provided for handling same. If these arrangements are bad, the ashes will interfere to a very considerable extent with the efficiency of the firing.

HEATING SURFACE.

This is efficient or non-efficient, from two main causes:

1. Position in relation to the current of gases and the distance the gases pass along the surface. Heating surfaces in which the circulation of water is at right angles to the current of gases are probably the most efficient.

2. Condition of heating surfaces as to cleanliness both inside and out. Dirt on inside of tubes is to be avoided by having surfaces so situated that dirt deposit is not likely to lodge on the heating surface, and by making such provision that dirt, when it does collect, can be readily removed.

Soot collecting on outside of tubes is to be avoided by the absence of lodging places and by providing for the cleaning of surfaces while boiler is steaming.

Proper consideration of these matters will increase the efficiency of the boiler to a very large extent, a fact which boiler manufacturers in many cases seem unable to grasp until after very costly experience.

The real relative steaming efficiency of any type of boiler can be determined only after long runs at full speed. The 4-hour trial trip is no criterion of service-steaming efficiency of a boiler, nor of its real economy and endurance.

The evaporative result of a boiler should be stated in boiler efficiency, that is, the per cent. the actual heat of steam generated bears to heat of the coal burnt. So much evaporation per pound of coal, without stating the kind and heating value of the coal, does not give a definite or fair comparison of boiler performance.

For purposes of proper comparison, there ought to be a standard pound of coal containing say 14,500 B.T.U. Then all results could be worked from this basis, and there would be some chance of a real unprejudiced and clear comparison of different tests.

EFFICIENCY OF MACHINERY FOR PROPULSIVE EFFECT.

This will depend on:

1. Greatest effective power developed in engines per unit of steam used. Economy of engines—this is perhaps the most potent factor of all; steam consumption of engines varying from 30 pounds to 12 pounds of water per I.H.P.

2. Most efficient use of power for propulsive effect (efficiency of propellers). By careful design an efficiency of nearly 70 per cent. can be obtained; in practice much lower efficiencies are found.

3. Least resistance at speed per ton of displacement for any displacement (efficiency of hull). This will depend on original lines to give least resistance at a certain displacement.

Other matters affecting this are: Smoothness of the surface of hull, extent of marine growth, frequent docking, efficiency of anti-fouling paints, sheathing, etc. These are all matters a full discussion of which would in each case involve a lengthy essay, though exact data on many of the points are not available and have not been determined.

It will thus be seen that a great many matters, not ordinarily considered as having any bearing on the question of fuel, have a very considerable effect on the coal endurance of a naval vessel. The following is a resumé of these items:

1. Bunker capacity in weight and space.
2. Kind of fuel.

3. Stowage of bunkers and facility for doing so.
4. Getting coal to fires and means for so doing.
5. General character and arrangement of fire rooms.
6. Skill of firemen and system of firing.
7. The detail and arrangement of furnaces.
8. Characteristics and arrangement of heating surface.
9. Arrangement provided for baffling gases.
10. Provisions for cleaning heating surface.
11. Evaporative efficiency of boiler as a whole.
12. Steam economy of engines and auxiliaries.
13. Mechanical efficiency of engine and shafting.
14. Efficiency of propellers.
15. Propulsive efficiency of lines of hull.
16. Condition of bottom.
17. Fuel used for purposes other than power for propulsion.

Any one of the above items and various others may have a very considerable effect upon the real steaming radius of a vessel. From this it should be seen that a calculated steaming radius based on bunker weight or space is most likely to be very misleading if some of the numerous other items vary. It can also be readily seen that steaming radius depends more on the character and design of boilers and machinery than it does on mere bunker capacity.

METHODS OF SUPPLYING FUEL.

The methods of supply must be viewed from the condition of affairs, not in ordinary time of peace, but in time of actual hostilities. The fallacy of building and preparing war material on a peace basis and for peace purposes is most harmful to military efficiency. To show its very harmful and misleading qualities it is but necessary to cite that it has been stated, in print, as a reason for *not* building a certain type of naval vessels "that they would be useful only in *time of war*."

In the matter of fuel supply, we want a system that will be useful in time of war. The question of its utility in time of peace should have but little weight.

The question of supplying a fleet with fuel in time of war is

a problem of transporting fuel from the source of supply to a movable fleet. In order that this fleet be supplied, it must either go to a permanent station or a movable station must come to it. If the fleet goes to the station, the fleet's military value is lost during that time. If the movable station can go to the fleet, the only time taken away from the military duties will be the actual time needed for transferring the fuel.

It is obvious that to supply a fleet during a campaign the movable fuel station or collier is the most desirable.

OUTLYING COALING STATIONS.

In time of war outlying coaling stations, unless protected at a practically prohibitive cost, are almost as useful to the enemy as to friends. To be of any real value they must be very numerous and located all over the world. The amount of coal stowed must be excessive, for an adequate supply must be at each station.

Any system of outlying coaling stations will require an enormous force for their proper protection and upkeep, and for supplying these stations colliers are also needed.

The fighting ships will, however, at various times have to return to a refitting point, which must be a properly protected place. At such a station coal must also be obtained. The number of vessels likely to require coaling at a certain point can only be known a short time before the fuel is actually needed; hence a permanent land coaling plant that is not susceptible to varieties in output is not and cannot be the desired appurtenance. The coaling plant must be one susceptible of expansion or contraction for the varying needs. It therefore follows that our present expensive coaling plants, located as they are at various points along the coast, some fortified, some not, some in conjunction with a refitting and revictualling place and some not, some located so that only small vessels can use them, are hardly what would seem the most desirable, and are certainly not really worth what has been spent on them. As a matter of fact, the type of coaling plants now built and building may be rightfully considered almost valueless as far as their

utility for purely military purposes is concerned; that is, for the actual operation of coaling fighting vessels in time of war. Might not just a little of the money that is being spent on these plants be used for an investigation and consideration of the question of the necessary and best-suited type of coal-carrying vessel for use in time of war?

The coaling apparatus at a refitting station should be a floating apparatus, so that any draught vessel can use it. The grave difficulties of going up a narrow channel to get alongside a coal wharf are thus obviated. The capacity can be increased to suit the probable movements of the fighting vessels. The supply of coal can be more readily replenished by any cargo boat, and the actual cost of the apparatus for the same total capacity will probably be less.

The type of such a movable coaling plant is a large barge, built so that if necessary it can be towed to sea. The barge should be fitted with coal-hoisting gear and a power plant for operating it. There should also be on board an electric-lighting plant and living quarters for the necessary attendants. Such barges should hold several thousand tons of coal; they could be anchored in a harbor; the fighting vessels could go alongside to get their coal, and the supply colliers bringing coal to them could unload alongside. If the harbor has a commercial coal-supply depot, these barges could be towed to such depots and loaded direct.

Smaller lighters should be used in conjunction with the large floating stations, for transporting coal as required to any point in the vicinity.

COLLIERS.

The purpose of fleet colliers should be to take the fuel from the various sources of supply and bring it to the fleet rendezvous or movable station, wherever that may be, and to supply coal to vessels on blockade.

GENERAL CHARACTERISTICS OF COLLIERS.

Speed.—The speed should be such that their maximum is the speed at which the battleship fleet might steam in squad-

ron. With our present battleships at 18 knots, a speed of 16 knots for colliers would seem to be the maximum desirable. In this connection it must be remembered that an extra knot above 16 requires a very large increase in power.

The displacement should be the largest compatible with a draught that will allow the vessel to come alongside the ordinary coal wharf of our harbors and to enter any ordinary harbor of importance. The draught, for these reasons, should not exceed 25 feet, and full load displacement would be limited to about 16,000 tons. With this displacement 10,000 tons of coal might be carried.

Every fleet collier should also carry oil and bulky stores, chiefly engineering stores, that require repeated replenishment. The securing of lubricating oil is even of more importance than coal.

The problem of supply could then resolve itself into—

1. Securing within various fortified harbors large storage barges, alongside of which men-of-war or fleet colliers can coal, and which are to be supplied by cargo steamers from the sources of supply. As supplementary to such floating stations, there ought to be a number of small coal barges which could be towed to vessels which might not find it convenient to come alongside of the large barge or which might not be able to do so.

2. A sufficient number of fleet colliers, specially designed for keeping up with a fleet at ordinary cruising speed.

3. Ordinary merchant colliers, chartered as needed, to transport coal to floating stations and to assist in bringing coal to the fleet when the resources of the regular colliers are overtaxed.

An adequate equipment of such fuel-supply facilities can be supplied at the cost of a few million dollars, which will be of real utility twenty years from now; yet, with all that has been spent in the last ten years on shore-coaling plants, we have hardly one that is of real practical use for coaling the fighting ship in time of war.

THE LOVEKIN IMPROVED OUTBOARD LOOSE COUPLING.

By Robert S. Riley.

The type of outboard loose coupling illustrated in Fig. 1 has been designed with a view to overcoming some of the objections inherent in the sleeve type which has been so generally used to connect the propeller and tail shafts in our large naval vessels.

It is well known that the old sleeve type, as illustrated in Fig. 2, involves some difficult problems in manufacture and fitting. But its compactness, strength and neat appearance have been such factors in its favor that no attempt has been made to supersede it. The couplings illustrated here are designed for 16½-inch shafts, such as are used for battleships of the *Kansas* class.

Shop men particularly appreciate the difficulty in machining the interior of the old sleeve coupling to the degree of accuracy which is absolutely essential for its efficiency. The long taper fits are an objectionable feature, and so are the cotter keys which pass through both shaft and coupling. But the most difficult work is the accurate cutting and fitting of the long keyways. It takes a special rig to plane such keyways properly. One of the best devices for this purpose is a heavy cast-iron column passing through the coupling and carrying a tool post. The coupling is fixed to the planer platen. The bar slides in supports attached to the platen, but gets its motion from the planer head. But such special rigs for work of this size and accuracy are very expensive.

The fitting of the long keys in the interior of the sleeve is a job which can be appreciated only when one considers that to get at the middle of the sleeve a man must reach in a distance of 32¾ inches (nearly 3 feet), and this through a hole only 16½ inches in diameter at the outside.

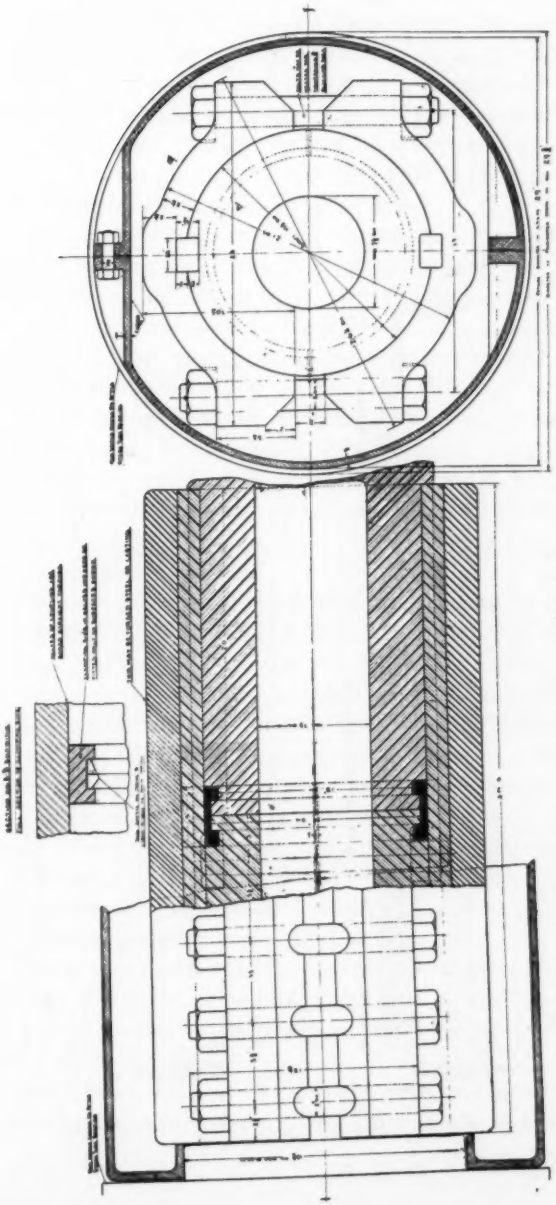


Fig. 1.

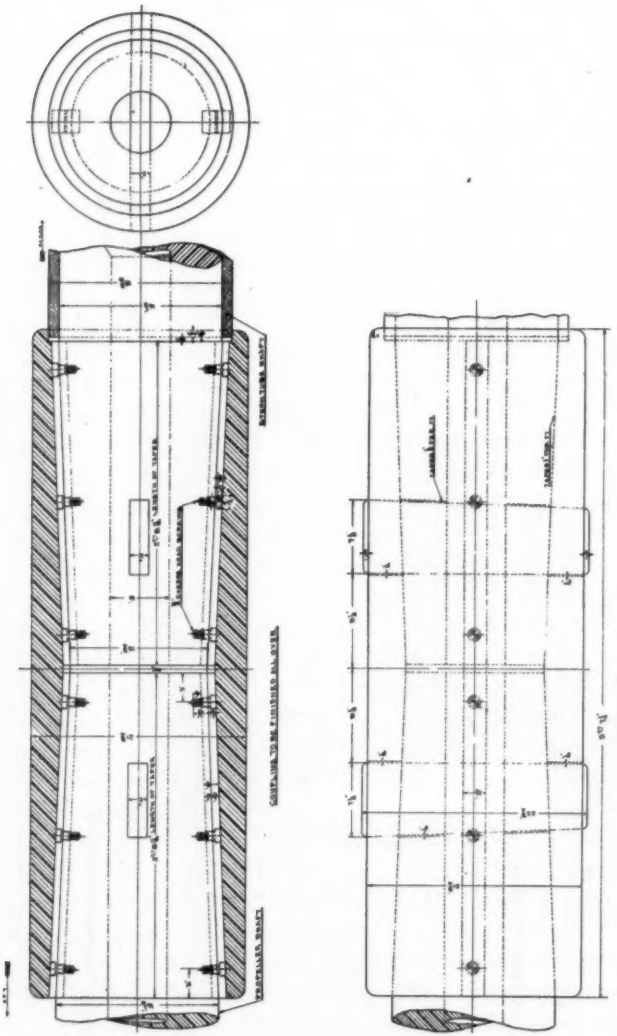


Fig. 2.

Even after the coupling is fitted there comes the question of its usefulness for the purpose intended. A loose coupling should surely be easily removable. But it will be readily seen that a very little corrosion in the interior would render this design anything but "loose;" in fact, its removal might become a very serious problem. It would not be hard to imagine a critical emergency arising from this cause.

The new type of clamp coupling shown is the idea of Mr. Luther D. Lovekin, Chief Engineer of the New York Shipbuilding Company, of Camden, N. J. It is now being built for use on the battleship *New Hampshire*. The advantages to be gained by this design of coupling may be summed up as follows:

1st. There are no difficult problems in its manufacture. There is not a taper fit anywhere. The boring is straight and parallel. The keyways are planed straight through and may be done without special tools, any number at a time, depending on the length of the planer bed. The clamping ring need fit only on two inside surfaces.

2d. The keys can be fitted accurately in place so as to get their proper distribution of the load. The coupling is assembled in pieces of convenient size and in such a manner that there is no uncertainty as to fit; whereas in the sleeve type of outboard coupling the work has to be done inside at different angles, and it is difficult to try the keys in place.

3d. The propeller shaft, weighing about 15,000 pounds, does not have to be moved in the process of fitting the coupling and keys. The ends of the shaft may be brought together in proper alignment, and all fitting and clamping done without further movement of the shaft. With the sleeve type the shaft and coupling have to be moved at each test.

4th. The reduced section of the shaft is not subjected to any stress either of torsion or bending; the only service required of the reduced section is the thrust of the propeller, and that only when going astern.

5th. There is no hole cut through the shaft as required for the cotters in the sleeve type. The drawing effect of these

cotters is uncertain, as the whole shaft has to be moved at each blow on the cotter, hence it is never known how closely the shaft fits the interior of the sleeve and keyway.

6th. The coupling is easily removed and replaced when necessary in ordinary service. The shaft need not be moved, and the parts of the coupling are of convenient size for handling. The clamping bolts can be readily expanded by the application of heat for the purpose of tightening or slacking back. Corrosion of the interior surfaces of the coupling and shaft cannot render the removal of the coupling impossible, as would be the case in the sleeve type.

7th. It is about 1,500 pounds lighter than the sleeve type, owing to reduced length. (This is 3,000 pounds in one ship.)

8th. It is of ample strength, as shown by calculations, and is safer than the sleeve type, owing to the fact that the stresses can be properly distributed by the accurate fitting made possible in its design.

It might be mentioned also that the design might be modified to suit the material to be used. For instance, if cast steel were used it might be desirable to change the form slightly, so as to have the coupling heavier at the center, where subject to the greatest torsion. The form shown is the simplest and plainest, so far as outside machining is concerned. In the *New Hampshire* the coupling is to be of forged steel.

To offset these advantages there are very few disadvantages to be urged. The increased volume necessary to clear the bolt heads and nuts is certainly no advantage; but as the diameter of the casing can still be less than that of the fair water to which it is adjacent, this is not a disadvantage.

Below are appended the calculations involved in this design. They show that the requirements are fully met in every particular.

CONDITIONS REQUIRED.

Horsepower = 16,500 total = 8,250 H.P. each shaft.

R.P.M = 120 = N.

Inch pounds per minute = $8,250 \times 33,000 \times 12$.

This represents the work imposed by the designed horsepower.

Let M represent the resulting moment or torque on the shaft in inch pounds.

With this moment the work done by the shaft will be $2\pi NM$ inch pounds per minute.

Hence, $8{,}250 \times 33{,}000 \times 12 = 2\pi NM$.

Therefore, $M = \frac{8{,}250 \times 33{,}000 \times 12}{2\pi \times 120} = 4{,}335{,}000$ inch pounds.

Diameter of propeller shaft:

Outside diameter $= 16\frac{1}{2}$ inches.
Inside diameter $= 9\frac{1}{2}$ inches.

The coupling is to be designed so as to be at least equal to the strength of the shaft at every point.

Moment of resistance to torsion in hollow shafts

$$= .1965\, S \frac{(D^4 - d^4)}{(D)}.$$

Where S = stress in pounds per square inch.
D = outside diameter.
d = inside diameter.

$D^4 = \overline{16\frac{1}{2}}^2 = 74{,}120.$
$d^4 = \overline{9\frac{1}{2}}^2 = 8{,}145.$
$D^4 - d^4 = 65{,}975$

$$M = .1965 \times \frac{65{,}975}{16.5} \times S.$$
$$= 785\, S.$$

Hence $S = \frac{4{,}335{,}000}{785} = 5{,}522$ pounds per square inch in the normal section of the shaft due to torsion.

Thrust on Coupling.

Indicated thrust $= \frac{\text{I.H.P.} \times 33{,}000}{P \times R}$.

P = pitch of propeller = 17.5 feet.
R = R.P.M. = 120.

Indicated thrust $= \frac{8{,}250 \times 33{,}000}{17.5 \times 120} = 129{,}600$ pounds.

For actual estimated thrust allow $\frac{2}{3}$ of 129,600=86,400 pounds.

To resist this thrust when going astern, fit the sectional ring as shown in drawing, so as to act as a clamp in holding the ends of the shafts together.

Find crushing stress imposed on the surface of the rings holding the sections of shaft together.

Outside diameter 14 inches—area=153.94
Inside diameter 13 inches—area =132.73
Net area= 21.21

From this subtract the amount cut out of clamping rings where they fail to meet, say $\frac{1}{4}$ inch $\times \frac{1}{2}$ inch $\times 2$=.25 square inches.

21.21
.25

Area subject to crushing=20.96, say 21 square inches.

Hence crushing pressure=$\frac{86,400}{21}$=4,120 pounds per square inch.

This is the same both in ring and shafts.

For shearing stress, consider the root of rings on shaft=13 inches diameter—circumference=40.84.

Deduct $\frac{1}{2}$ inch for open space between ends of clamping ring, leaving 40.34 inches.

Length of 1 inch depth=40.34 square inches.

Hence shearing stress=$\frac{86,400}{40.34}$=2,090 pounds per square inch.

For tensile stress on ring when the shafts are trying to separate there is no need for calculation, as it is obviously much less per square inch than either the crushing or shearing stresses.

Note.—From calculations later, on the clamping effect of the bolts, the resistance due to surface friction=92,000 pounds. This is greater than the estimated thrust=86,400 pounds.

Hence the above stresses on the rings can never be attained and the rings may not be used at all.

Stress on Keys.

Twisting moment=4,335,000 inch pounds.

Keys are to resist this torque.

Use two keys 1½ inches deep=¾ inch deep in shaft and coupling.

Diameter of center of keys=16½ inches and radius (or arm) =8¼ inches.

Shaft keyway is subject to greatest stress because the arm of its moment is less.

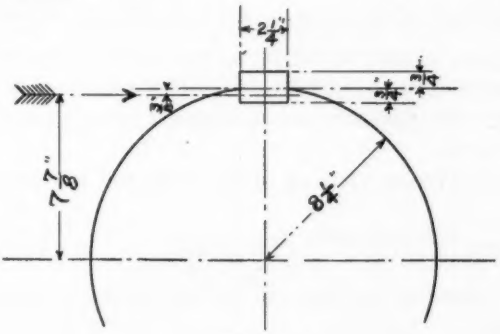


Fig. 3.

Radius of center of crushing forces in shaft keyway=8¼ inches—½ of ¾ inch=7⅞ inches=7.875 inches, assuming forces concentrated at center of bearing surface of keyway. See Fig. 3.

$$\text{Pounds pressure at that arm} = \frac{\text{moment}}{\text{radius}}.$$

$$= \frac{4{,}335{,}000}{7.875}.$$

=550,000 pounds for both keys.

=275,000 pounds for each key.

Length of key=20 inches in each shaft.

Area of side of keyway in shaft=¾ inch × 20 inches.

Hence, crushing stress $= \frac{275{,}000}{\frac{3}{4} \times 20}$

$= 18{,}320$ pounds per square inch.

Width of key $= 2\frac{1}{4}$ inches.

Area of two keys to resist shear $= 2\frac{1}{4}$ inches $\times$ 20 inches $\times$ 2.

Arm of shearing stress $= 8\frac{1}{4}$ inches.

Hence, shearing stress $= \frac{4{,}335{,}000}{2\frac{1}{4} \times 20 \times 2 \times 8\frac{1}{4}}$

$= 5{,}840$ pounds per square inch.

Note.—These stresses on keys are decreased by the clamping effect of the loose coupling. See other calculation later.

CLAMPING POWER OF 16 BOLTS 2 INCHES DIAMETER.

At 5,000 pounds stress per square inch at root of thread, the pressure due to one bolt $= 11{,}500$ pounds.

Hence the pressure of 16 bolts $= 16 \times 11{,}500 = 184{,}000$ pounds total.

This is over an area 44 inches long and $16\frac{1}{2}$ inches diameter.

Width $= \frac{\text{circumference}}{2} - 2$ inches $= \frac{51.8}{2} - 2$ inches $= 23.9$ inches (allowing for space where the halves of coupling fail to meet).

Pressure per square inch $= \frac{184{,}000}{44 \times 23.9} = 175$ pounds.

At this pressure the coefficient of friction for wrought or cast steel will be at least .25 (friction of rest—unlubricated).

Hence, resistance of the entire surfaces of the coupling $= 184{,}000 \times .25 \times 2 = 92{,}000$ pounds. This is along the surface of the shaft.

Hence, the moment $= 92{,}000 \times 8\frac{1}{4}$ inches radius,

$= 759{,}000$ inch pounds.

This may be subtracted from the moment for which the keys were designed $= 4{,}335{,}000$

$759{,}000$

Leaving $3{,}576{,}000$ inch pounds.

Pressure of this moment at radius $7\frac{7}{8}$ inches (see Fig. 1)

$$=\frac{3{,}576{,}000}{7.875}=454{,}000 \text{ pounds.}$$

Hence, pressure per square inch on the keys would be

$$\frac{454{,}000}{2\times 20\times\frac{3}{4}}=15{,}130 \text{ pounds per square inch (say 15,000),}$$

and shear would be $\frac{3{,}576{,}000}{8\frac{1}{4}\times 2\frac{1}{4}\times 20\times 2}=4{,}810$ pounds.

The total effective thrust of the engines is 86,400 pounds (approximately); hence the friction might be more than sufficient to dispense with grooves entirely.

Moment of resistance to torsion of loose coupling.—Section at end of keys:

Area = as measured by planimeter from drawing = 159.04 square inches.

Outside diameter (approximately) = 21 inches = D.

Inside diameter (approximately) = $16\frac{1}{2}$ inches = d.

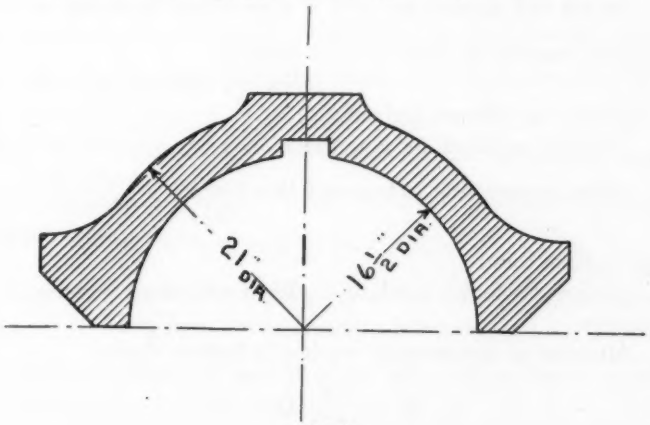


Fig. 4.

Assume that the forces may be considered acting at the center line of a longitudinal section, the same as for a thin shell. See correction later.

The radius of which is a mean between the inner and outer radii $= \frac{1}{4}(D + d) = \frac{37.5}{4}$.

Area of transverse section under consideration = 159.04 square inches.

(Area of complete ring between similar diameters =

$$\frac{\pi}{4}(D^2 - d^2) = 132.5.)$$

Moment of the section to resist torsion = stress per square inch × area × arm = $S \times 159.04 \times \frac{37.5}{4}$.

To allow for the inaccuracy of this method between these diameters, multiply this moment by .905, as calculated. See in note later.

$M = S \times 159.04 \times \frac{37.5}{4} \times .905 = 1{,}349$ "S" inch pounds.

Moment for the normal section of shaft = 785.S inch pounds.

Hence the section is $\frac{1{,}349}{785} = 1.72$ times as strong as the normal section of shaft to resist torsion.

= 72 per cent. stronger (but is required for stiffness and safety.)

Moment required for 8,250 H.P. = 4,335,000 inch pounds.

Stress in coupling to transmit this torque = $\frac{4{,}335{,}000}{1{,}349}$.

= 3,210 pounds per square inch.

Note.—Re factor used to modify moment of resistance to torsion.

Moment of resistance to torsion in hollow shafts.

$$M = \frac{\pi S}{16D}(D^4 - d^4).$$

$D = 21$ inches.

$d = 16\frac{1}{2}$ inches.

$$M = \frac{\pi S}{16}\frac{(120{,}361)}{21}.$$

$$= \frac{\pi S}{16} \times 5{,}731.5, \quad . \quad . \quad (A)$$

This is the correct moment of resistance for this shaft.

Now consider this shaft as a circular ring for purposes of comparison.

$$\text{Area} = \frac{\pi}{4}(D^2 - d^2).$$

Radius of center of gravity of longitudinal cross section

$$= \frac{1}{4}(D+d).$$

The moment of resistance to torsion by this method is therefore,

$$M = S \times \frac{\pi}{16}(D^2 - d^2) \times (D+d).$$

$$M = \frac{\pi}{16}(168.75 \times 37.5).$$

$$= \frac{\pi}{16} \times 6{,}328.125, \quad . \quad . \quad . \quad (B)$$

This is an approximation of the moment worked out in the same manner as assumed for the cross section of the coupling.

This shows that the latter method gives a value of $\frac{6{,}328}{5{,}731}$ times too great for the diameters chosen.

Hence, results on this method with similar dimensions must be multiplied by $\frac{5{,}731}{6{,}328} = .905$ in order to get the correct value of the moment of resistance to torsion.

To find diameter of hole required and have the shaft equal to original before keyways were cut out.

Radius of center of gravity of keyway $= 8\frac{1}{4}$ inches $- \frac{3}{8}$ inch $= 7\frac{7}{8}$ inches.

Area of keyway $= \frac{3}{4}$ inch $\times 2\frac{1}{4}$ inches $= 6\frac{3}{4}$ square inches.

Moment of resistance to torsion of this material cut out of these keyways will be approximately the moment of their shearing values $= 6\frac{3}{4} \times S \times 7\frac{7}{8} \times 2$.

This must be compensated for by a hollow shaft inside the original, of which $D = 9\frac{1}{2}$ inches.

$$D^4 = 8{,}145.$$
$$d = ?$$

The moment of resistance of the shaft must therefore equal the above moment of the material cut out for keyways.

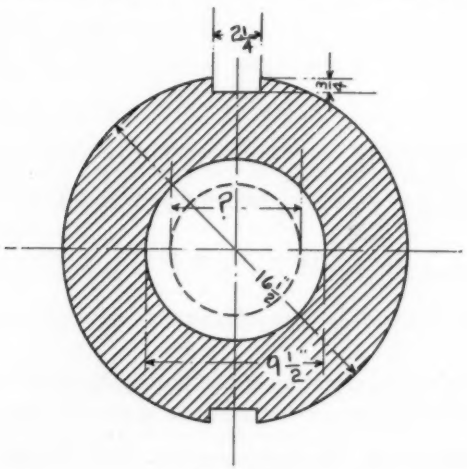


Fig. 5.

Hence, $\frac{\pi S}{16D}(D^4 - d^4) = S \times 6\frac{3}{4} \times 7\frac{7}{8} \times 2.$

and $d^4 = \frac{-6.75 \times 7.875 \times 2 \times 9.5 \times 16}{3.1416} + 8{,}145$

$= 8{,}145 - 5{,}140 = 3{,}005.$

$d = 7.704$ (say $7\frac{3}{4}$ inches).

Make diameter of hole $= 7\frac{1}{2}$ inches. (Ample.)

ACTION OF KEYS IN SPREADING THE COUPLING.

The driving pressure F on one side of the shaft key seat at radius $7\frac{7}{8}$ inches is 275,000 pounds, previously calculated.

Hence, resisting pressure R in the coupling at radius $8\frac{3}{8}$ inches $= 275{,}000 \times \frac{7\frac{7}{8}}{8\frac{3}{8}} = 251{,}000$ pounds.

These pressures both act against each other at arms of $\frac{3}{8}$ inch each.

Therefore, total moment $= \frac{3}{8} \times 275{,}000 + \frac{3}{8} \times 251{,}000$
$= 197{,}250$ inch pounds.

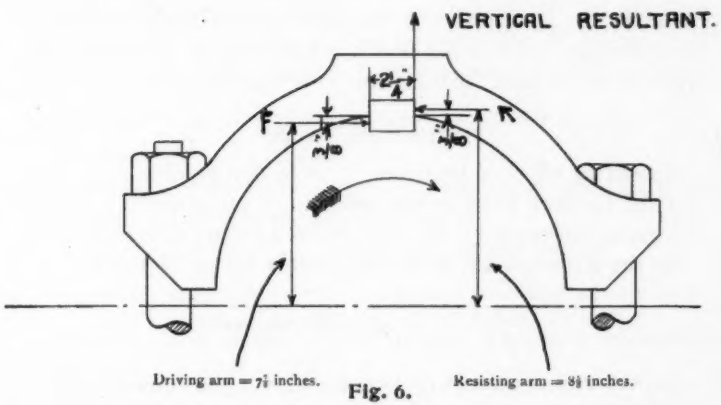


Fig. 6.

This may be considered a moment tending to roll the key in the direction indicated in Fig. 7. It is resisted by the vertical forces p and p_1, which act at an arm equal to width of key $= 2\frac{1}{4}$ inches.

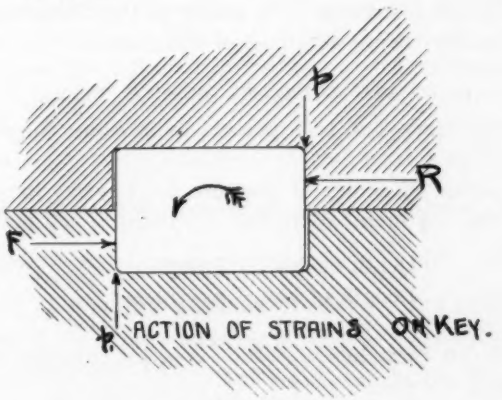


Fig. 7.

Hence the vertical pressure due to the moment tending to roll the key $= 197{,}250 \div 2\frac{1}{4}$ inches $= 87{,}670$ pounds.

This is, therefore, the force which the bolts have to resist in keeping the halves of the coupling together.

Note.—The driving and resisting forces do not act on planes radial to the axes, and this has a further tendency to spread the coupling, but it is not worth considering in this case, the angle being so small that its sine is practically zero.

STRESS ON BOLTS.

Spreading effect of each key = 87,670 pounds.
Total for both keys on one side = 175,340 pounds.
This is overcome by the 16 bolts of 2 inches diameter.
So the stress on the bolts due to this action of the key =

$$\frac{175{,}340}{16} = 10{,}960 \text{ pounds each.}$$

Area of 2-inch bolts at root of thread = 2.302 square inches.
Hence, stress per square inch on bolts =

$$\frac{10{,}960}{16} = 4{,}760 \text{ pounds.}$$

This is a safe margin for the bolts, for the keys cannot set up even so much stress as this, owing to the clamping effect of the coupling taking off a part of their work.

OUTBOARD COUPLING, SLEEVE TYPE.

Moment = 4,335,000 inch pounds to transmit 8,250 horse-power.

Mean radius of center of pressure for keyway in shaft = $\frac{1}{2}$ ($8\frac{1}{4}$ inches $- \frac{3}{8}$ inch $+ 6\frac{7}{8}$ inches $- \frac{3}{8}$ inch) = $7\frac{3}{16}$ inches.

Depth of key = $\frac{3}{4}$ inch.
Length of key = $32\frac{3}{4}$ inches.

Pressure on each key = $\frac{4{,}335{,}000}{7\frac{3}{16}} \times \frac{1}{2} = 301{,}350$ pounds.

Crushing pressure = $\frac{301{,}350}{\frac{3}{4} \times 32\frac{3}{4}} = 12{,}250$ pounds per square inch.

Width of key = $2\frac{1}{4}$ inches = $\frac{3}{4} \times 3$.

Hence, shearing stress $= \frac{1}{2}$ of crushing pressure (approximately) $= 4{,}080$ pounds per square inch.

Note.—Both these stresses are very moderate, but are sure to be greatly increased by the impossibility of fitting keys inside of long sleeve so that they will receive uniform stress.

Stresses on cotter key driven through shaft and coupling.

Width of key $= 2$ inches.

Depth in contact with sleeve $= 3\frac{1}{2}$ inches at each end.

Hence, area of key under compression $=$

2×2 inches $\times 3\frac{1}{2}$ inches $= 13$ square inches.

$$\text{Crushing pressure} = \frac{83{,}560}{13} = 6{,}428 \text{ pounds per square inch.}$$

Shearing area of key $= 2 \times 2$ inches $\times 7$ inches $= 28$ square inches.

$$\text{Shearing stress} = \frac{83{,}560}{28}$$

$= 3{,}000$ pounds per square inch.

Note.—These stresses are in addition to the initial stresses set up by driving the cotter keys into place; this, of course, may be anything, depending on the weight of sledge, etc., used for driving in. When drawing the last shaft into place in the sleeve, the tail shaft, weighing over 15,000 pounds, must be moved at each blow on the cotter. The great inertia of this weight necessitates a great stress on the cotter in order to move it, and leaves a doubt as to whether it is all the way in.

Stress on sleeve at junction of shafts due to torsion.

$$\text{Moment} = 4{,}335{,}000 \text{ inch pounds} = \frac{\pi S}{16D}(D^4 - d^4).$$

Where $D =$ outside diameter of sleeve $= 21\frac{3}{4}$ inches,

Where $d =$ inside diameter of sleeve $= 13\frac{3}{4}$ inches,

$$S = \frac{4{,}335{,}000 \times 16 \times D}{\pi \times (D^4 - d^4)} = 2{,}450 \text{ pounds per square inch.}$$

This is very moderate, and shows that less metal could be used by making the sleeve less in diameter at its middle, and still have ample strength.

L. D. LOVEKIN PATENT LOOSE COUPLING AS DESIGNED FOR OUTBOARD-SHAFT COUPLING OF U. S. BATTLESHIP "*KANSAS.*" COMPARISON WITH TYPE ADOPTED BY U. S. NAVY.

	U. S. Navy, sleeve type.	Lovekin, clamp type.
Weight of coupling complete, except casing. This weight is the excess over the normal section of shafting of 16¼ inches outside diameter, 9½ inches inside diameter, pounds, approximately	3,925	2,515
Difference in types, pounds	1,410	
Two keys on each shaft, dimensions, inches	1½×2½×32½	1½×2½×20
Crushing pressure on keys to resist torsion, pounds per square inch	12,250	†18,320
Shearing force on keys to resist torsion, pounds per square inch	4,080	†5,840
Crushing pressure to resist thrust of propeller, pounds per square inch	*6,428	††4,120
Shearing force to resist thrust of propeller, pounds per square inch	*3,000	††2,090
Stress in coupling opposite junction of shafts due to torsion, pounds per square inch	2,450	3,210
Stress due to torsion in normal section of shaft, pounds	5,500	5,500
Diameter of hole in shaft at coupling, inches	6	7½

* These are the stresses in cotter key when going astern, in addition to initial stress due to driving in.

† These stresses are materially decreased by the clamping effect of the Lovekin coupling. The corresponding stresses in the sleeve type are especially liable to increase due to the impossibility of fitting accurately.

‡ These are the stresses in clamping ring when going astern.

DESCRIPTION OF STEAMSHIP *DAKOTA* AND HER OFFICIAL TRIAL PERFORMANCE.

By A. GUNDERSEN, ASSOCIATE.

Steamship *Dakota* is the sister ship of steamship *Minnesota*, designed by Mr. Charles R. Hanscom and built by the Eastern Shipbuilding Company, New London, Connecticut, for the Great Northern Steamship Company's trans-Pacific line between Seattle, Wash., and the Orient.

Steamship *Dakota* is of the type called intermediate, which has of late years become so popular on the Atlantic—that is to say, she is designed neither for passenger service exclusively nor for cargo carrying only, but for combined cargo and passenger traffic in conjunction with the Great Northern Railway Company.

The vessel has accommodation for 206 cabin passengers, 66 intermediate cabin passengers, 735 troops or steerage passengers and a crew of about 250 men.

The first-cabin staterooms are located in the midship house above upper deck and on main deck aft of machinery space. The first-cabin dining saloon is on the upper deck, in the forward end of the midship house, with a seating capacity of 190 passengers. From the dining saloon a grand stairway leads to the promenade-deck hall, at the forward end of which are located the library and ladies' boudoir. Two stairways lead from promenade to the bridge-deck social hall.

The smoking room is located on the bridge deck, forward of the engine hatch casings; extends the full width of the house, and is arranged in a convenient manner. Immediately abaft of the smoking room, between the engine-room hatch casings, are the barroom, toilet rooms and the barber shop. On the promenade and bridge decks several commodious suites are arranged, consisting of bed room, sitting room and bath room.

The good features in this passenger accommodation are the splendid, wide promenade spaces, the light and airy halls, staterooms and corridors, the facility of getting from one deck to another and accessibility of toilet rooms.

The intermediate-cabin passengers are located on the main deck, forward of hatch No. 5, and the troops or steerage passengers are on the same deck abaft of first-cabin staterooms.

The captain and officers are located in a large house on boat deck, and the chief engineer, assistant engineers, chief electrician and junior engineers have rooms on port side of main deck, abreast of machinery space.

The passenger and crew spaces are ventilated mechanically in addition to the usual natural ventilation. Fresh air is supplied into the passages and the vitiated air is exhausted direct from the rooms. In all large public rooms the exhaust is in the ceiling and the supply comes in at sides. The fresh air supplied to living quarters by the mechanical ventilation is cleansed and heated or cooled by passing over coils for that purpose.

The galleys are on the main deck forward of boiler hatch casing; they are divided by a passage which leads from the first-cabin buffet pantry, adjoining the café on starboard side of main deck, and the officers' pantry, between the main boiler uptakes, to the intermediate-cabin pantry. The first-cabin pantry is on the upper deck, immediately over the galley; communication between the two is by dumb waiter and stairway. At the forward end of the passageway above referred to, and close to the intermediate-cabin pantry, an electric elevator leads to the ship provision storerooms below.

The quartermasters, boatswains, carpenters, water tenders, electric and refrigerating engineers are berthed in the forward deck house on upper deck, which also contains the refrigerating machinery. The laundry men have their quarters in the after deck house on upper deck, in the same house as the laundry machinery is located. The waiters, oilers, seamen and firemen are berthed forward. They are divided into watches and have wash and toilet rooms conveniently near their quarters.

The hull is constructed of open-hearth steel throughout and built to class 100-A1 Lloyd's awning-deck type.

The double bottom is six feet deep at center, built on the cellular system, extending the entire length of the vessel and divided into twenty-nine watertight compartments. The longitudinal bulkhead, which is 18 inches off center and directly over the starboard vertical keel, extends from end to end of vessel, from tank top to main deck, thus dividing her into two parts. The hull is divided transversely by bulkheads into thirteen watertight compartments. The peak bulkheads are watertight from tank top to upper deck, and the other transverse bulkheads to main deck.

The cargo hatches are in pairs, one for each hold, on each side of the longitudinal bulkhead.

The five lower decks are of steel, continuous the entire length of hull, and the three steel decks in the midship deck house are fitted with expansion joints.

PRINCIPAL DIMENSIONS OF HULL.

Length between perpendiculars, feet and inches	608- 0
over all, feet and inches	627- 9
Beam, extreme, feet and inches	73- 6
Depth of ballast tanks at center, feet and inches	6- 0
Height from tank top to orlop deck at center, feet and inches	9- 6
orlop deck to lower deck, feet and inches	9- 6
lower deck to 'tween deck, feet and inches	9- 6
'tween deck to main deck at side, feet and inches	11- 6
main deck to upper deck, feet and inches	8- 0
upper deck to promenade deck, feet and inches	8- 6
promenade deck to bridge deck, feet and inches	8- 0
bridge deck to boat deck, feet and inches	8- 0
boat deck to captain's bridge, feet and inches	7- 8
upper navigating bridge to bottom of keel, feet and inches	88- 4
Shear forward on upper deck, feet and inches	8- 6
aft on upper deck, feet and inches	6- 6
Block coefficient at a draught of 32 feet 6 inches	0.76
Prismatic coefficient at a draught of 32 feet 6 inches	0.80
Coefficient of fineness of 32 feet 6 inches water line	0.88
Gross tonnage, measured by U. S. custom officials	20,714.32
Net tonnage, measured by U. S. custom officials	13,305.58
Total water ballast, including fresh-water tanks in double bottom, tons	4,000

Total capacity of fresh-water tanks, tons	1,314
coal bunkers, including reserve bunkers, tons	5,226
deadweight carrying capacity in tons of 2,240 pounds	22,250
Displacement when fully loaded to a draught of 38 feet (Plimsoll mark), tons	37,500

MAIN ENGINES.

There are two main engines, each in a watertight compartment. They are outboard-turning, direct-acting, three cylinder, triple-expansion engines, built by the Midvale Steel Co., Philadelphia, Pa. The arrangement of cylinders and valves is as follows, commencing forward: High-pressure cylinder; high-pressure piston valve; low-pressure cylinder; low-pressure double-ported slide valve; middle-pressure cylinder and the middle-pressure piston valve at the after end.

The cylinders and steam chests are of cast iron, in four separate castings, bolted together. The H.P. cylinder and chest, the M.P. cylinder and chest, the L.P. cylinder and the L.P. valve chest, each being separate castings.

Distance pieces are placed between high and low-pressure cylinders, and between M.P. cylinder and L.P. valve chest, allowance being made for expansion. The H.P. steam chest has an 11-inch diameter opening on column side for connection of steam stop valve, and exhausts into a cast-iron T pipe, 15½ inches in diameter, bolted to H.P. chest at back, thence through a 15½-inch copper pipe with a slip joint at M.P. chest. The M.P. cylinder exhausts through two rectangular passages, each 18 inches by 12½ inches, made a part of cylinder casting, while the L.P. cylinder exhausts through a 32-inch diameter copper pipe, with a slip joint at condenser.

The clothing material for all cylinders and steam chests is composed of 85 per cent. carbonate of magnesia, and 15 per cent. asbestos fiber, lagged with galvanized steel plates with vertical joints.

The framing is of three cast-iron inverted Y housings on the inboard side, with six heavy wrought-steel columns on the outboard side, the housings carrying the guides, reversing engine and brackets for reversing-shaft bearings, and the col-

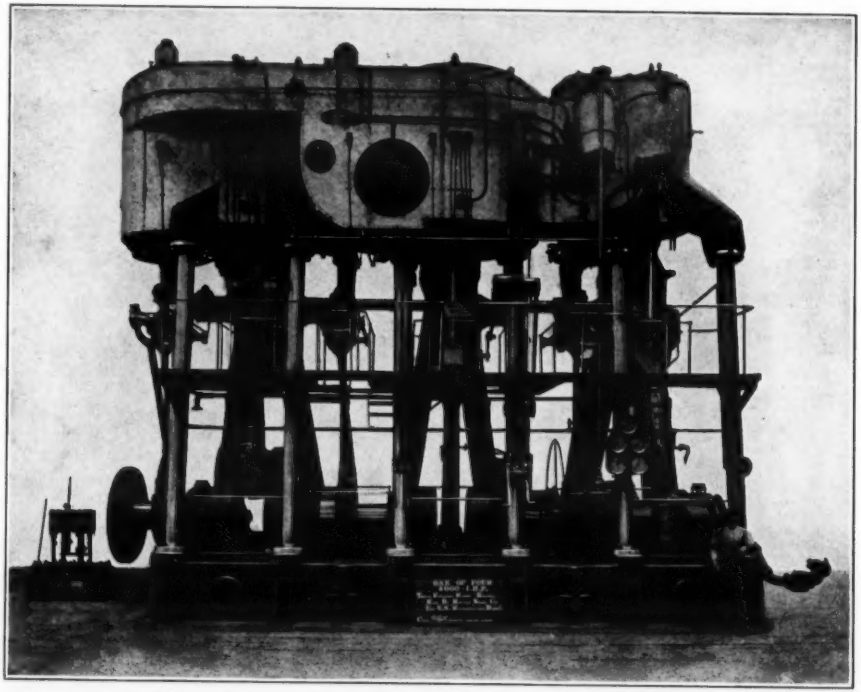


Fig. 1.

umns carrying the handling and drain gear. The framing is of such proportions as to be thoroughly stiff and rigid, obviating the use of bracing beyond tieing the engines together with athwartship ties at top of housings.

The bed plate is of cast-iron, box section, very deep, and in three sections. The bottom is made to suit the tank top, being firmly bolted to same with one hundred and fifty-eight 1½-inch stud bolts in each bed plate, screwed into tank-top plates and flange of stiffeners with nuts underneath.

There are two main bearings to each crank shaft, and the main bearing caps are of cast steel, lined with Parsons white metal ⅝-inch thick; the bottom boxes are also of cast steel, with composition bushes lined with the same metal of the same thickness as in caps. The bottom boxes are circular, to facilitate removal without lifting of crank shafts.

All the cylinders are jacketed around the working liners. A 1½-inch copper pipe connected to throttle-valve casing supplies steam at working pressure to the high-pressure jackets, and from thence, by Leslie's reducing valves, goes to the M.P. and L.P. jackets, the drop in pressure causing the re-evaporation of the condensed water. This insures all jackets being perfectly drained, and limits the waste due to passage of steam with water through the trap from the one connection at bottom of L.P. jackets.

The cylinder and valve-chest covers are of cast iron, of the box section, and have rolled diamond plates on top. The high and middle-pressure valve-stem guide brackets are cast on the bottom valve-chest covers, and the low-pressure valve-stem guide bracket is bolted to the bottom of low-pressure valve-chest cover. The valve-stem guides are fitted with hard composition boxes, in halves, and held in place by the cap bolts. All the main valves are operated by Stephenson double-bar, link motion with adjustable cut-offs, actuated by screws in slotted arms on the reversing shaft, which may be varied from 0.513 to 0.798 of stroke for H.P., 0.514 to 0.731 for M.P., and 0.526 to 0.731 for L.P. All valves have a common stroke of 10 inches when reversing links are in their normal position. The

middle and low-pressure valves are fitted with Joy's assistant cylinders, 6¾ inches and 8¾ inches diameter, respectively, while the high-pressure valve is partially balanced by having its upper portion enlarged in diameter. The low-pressure, as before stated, is a double-ported slide valve, and a circular relief frame, 56½ inches outside diameter, is fitted to the L.P. valve-chest on which the back of valve slides. The space inside of this relief ring has a 1-inch pipe connected to the main exhaust pipe.

For further information of valve motion see valve diagram and tables of valve events on Fig. 2.

The body of all main valves is of cast iron; the H.P. and M.P. piston valves have each two solid cast-iron packing rings top and bottom, and the L.P. slide valve works on a cast-iron false face, 1¾ inches thick, bolted to the L.P. cylinder face.

The handling gear, located on the column side of engine (outboard side), is operated from the working platform on the engine-room floor.

On the after column of H.P. cylinder is an 18-inch diameter hand wheel operating the stop valve, which is of the piston balance type, 11 inches in diameter, bolted to the front of H.P. steam chest.

The cock admitting steam to the balance piston is worked by a lever at the same column. At the forward column of the low-pressure cylinder are the levers for throttle valve and reversing engine and the hand wheels for opening and closing the pass-over valves to M.P. and L.P. receivers.

The throttle valve is of the butterfly type, 11 inches in diameter, bolted to the under side of stop valve. This valve is automatically controlled by an Aspinall governor, which is carried on a special lever worked from the low-pressure crosshead. The governor commences to act at seventy-five revolutions per minute, and at ninety revolutions per minute the throttle valve is shut. A disconnecting arrangement is provided for disconnecting the governor gear, enabling the throttle to be worked directly by the hand lever.

On the after column of the low-pressure cylinder are the

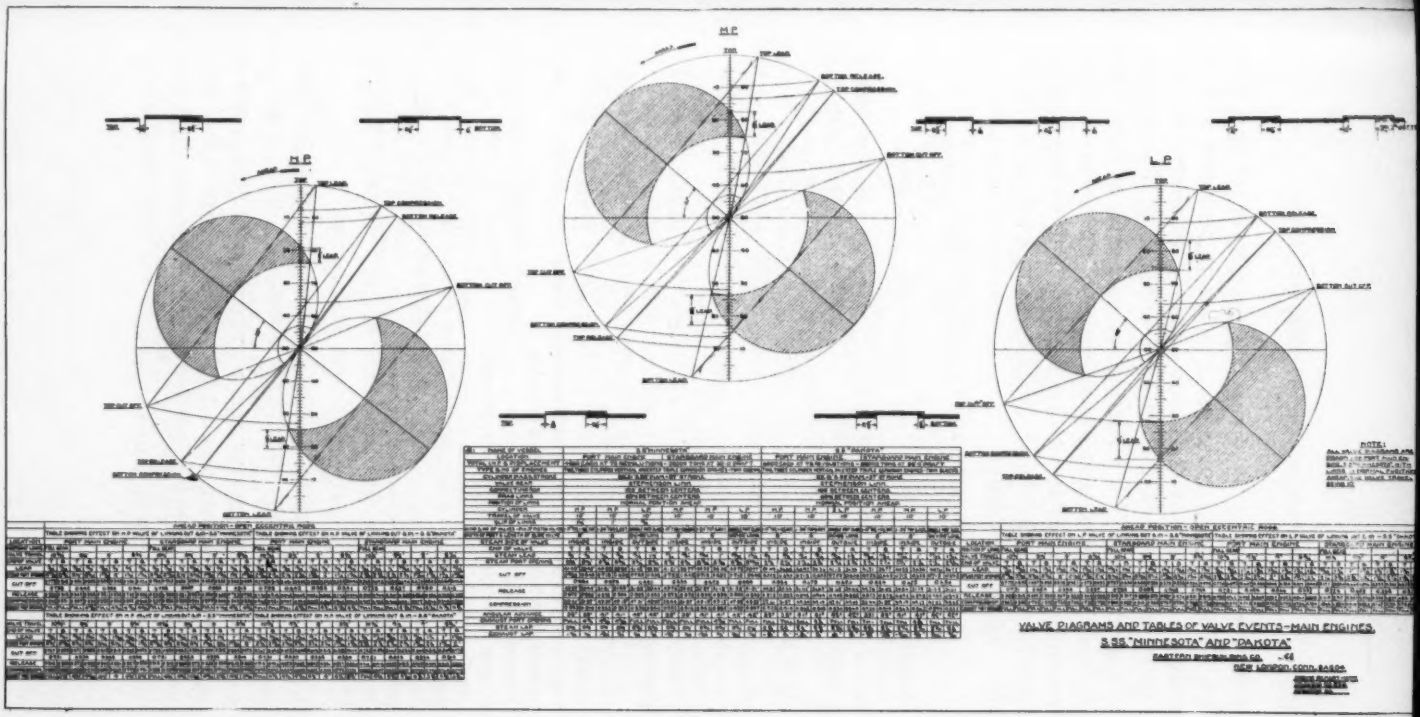

H.P.
L.P.
VALVE DIAGRAMS AND TABLES OF VALVE EVENTS - MAIN ENGINES.
S.S. "MINNESOTA" AND "DAKOTA".

Fig. 2.

levers for operating the drain cocks, one lever for each cylinder. The cylinder cocks are 2 inches in diameter, and the steam chest cocks are 1¼ inches diameter, connected by separate levers to a 1¼-inch shaft, led fore-and-aft at front of upper column flanges. The operating lever for each cylinder opens or closes the cylinder and chest drains of that cylinder simultaneously. Particular care has been taken to arrange the passages as well as the relief valves so as to keep the cylinders and ports clear of water.

CYLINDER AND VALVE-CHEST DATA.

	H.P.	M.P.	L.P.
Diameter of cylinders, inches	29	51	89
Stroke, inches	57	57	57
Area of cylinders, square inches	660.5	2,042.8	6,221.1
Volume of cylinders, cubic inches	37,648.5	116,439.6	354,602.7
piston rods, cubic inches	2,865	2,865	2,865
Cut-off of stroke, top	0.71	0.712	0.712
bottom	0.64	0.638	0.638
Clearance, top :			
In cylinders, cubic inches	307	1,084	2,627
Ports and passages, cubic inches	5,000	15,500	24,239
Total, cubic inches	5,307	16,584	26,866
Clearance, bottom :			
In cylinders, cubic inches	381	1,578	4,305
Ports and passages, cubic inches	5,148	16,144	26,046
Total, cubic inches	5,529	17,722	30,351
Avge. perctge. clearance, top and bottom,	14.96	14.91	8.1
Volume of cylinders to cut-off, top, cubic inches	26,730	82,905	252,477
Volume of cylinders to cut-off, bottom, cubic inches	22,261	72,461	224,409
Volume of cylinders to cut off, average, cubic inches	24,495.5	77,683	238,443
Volume of cylinders to cut off, average, including clearance, cubic inches	29,913.5	94,836	267,051.5

Ratio of expansion :

$$\text{Nominal ratio} = \frac{\text{Vol. L.P}}{\text{Vol. H.P. to C.O.}} \ldots\ldots 14.48$$

without regard to clearance and release.

$$\text{Ratio} = \frac{\text{Vol. L.P. and clearance}}{\text{Vol. H.P. to C.O. and clearance}} \ldots\ldots 12.81$$

not considering release in L.P.

$$\text{Actual ratio} = \frac{\text{Vol. L.P. to release and clearance}}{\text{Vol. H.P. to C.O. and clearance}} \ldots\ldots 11.63$$

release in L.P. cylinder = 0.9 stroke.

	H.P	M.P.	L.P.
Thickness of cylinder body, inches	1⅝	1⅝	1⅝
liner, inches	1⅝	1⅝	1⅝
jacket space, inches	1½	1½	1½
valve-chest liner, inches	1 5/16	1½	...
Number of studs for cylinder cover	31	38	48
Diameter of studs for cylinder cover, inches	1½	1½	1½
stud pitch circle, cylinder cover, inches	38	60	98
Number of studs for valve-chest cover	14	20	34
Diameter studs, valve-chest cover, inches	1½	1½	1½
pitch circle, chest cover, inches	25	39½	87
Number tap bolts for cylinder liner	26	32	52
Diameter tap bolts for liner, inches	1½	1	1
pitch bolt circle liner, inches	...	49	87
Number of piston valves	1	1	...
double-ported slide valves	...	...	1
Diameter piston valves, inches { top	17	34	...
Diameter piston valves, inches { bottom	16½		
Size of slide valves, inches			59×95
Depth of steam port, inches	5	5	(2)3½
Width of steam port, inches	31	61	88
Diameter cylinder relief valve, top and bottom, inches	3	4	6

PISTONS.

The H.P. piston is of cast iron, flat, and of hollow section; the other pistons are of cast steel, conical in shape. All piston followers, bull rings and packing rings are of cast iron. The packing rings are designed to prevent expansion beyond a given diameter, but allow lineal expansion.

	H.P.	M.P.	L.P.
Depth of piston, over all, inches	10	23¾	23¾
at periphery, inches	10	8½	8½
Number of packing rings	2	2	2
Width of packing rings, bearing surface, inches	1	1⅛	⅝
Thickness of packing rings, inches	1½	1½	⅞
Number of follower bolts	6	12	20
Diameter of follower bolts, inches	1½	1½	1½

PISTON RODS AND VALVE STEMS.

The piston rods and valve stems are of high-grade carbon steel, finished all over and oil tempered. The ends of piston rods are tapered to fit the pistons and crossheads. The lower end of valve stems is forged large enough for composition bush. The cap and the lower box are cast in one, of the same hard composition as the top half. Piston rods and valve-stem

stuffing boxes are fitted with Katzenstein's metallic packing, and have a small stuffing box for soft packing on the outside of the metallic packing.

Diameter of piston rods, inches	8
threads, top and bottom, inches	6
Length piston rods, over all, inches	129
Diameter valve stems through guide and gland, inches	5½
valve, inches	4
Number of bolts in valve-stem brasses	2
Diameter bolts in valve-stem brasses, inches	2¼

MAIN VALVE LINKS AND LINK BLOCKS.

The links and link blocks are of high-grade carbon steel, finished all over and oil tempered.

The link blocks have at each end a pair of jaws to span the corresponding bar of the link. The jaws are fitted with composition gibs, finished to the curve of the links, and have tap bolts for adjustment. The pins for suspension rods are in the center of links.

Depth of link bars, inches	6½
Width of link bars, inches	2¼
Distance between bars, inches	8¼
pins for eccentric rods, inches	30
Diameter of pins for eccentric rods, inches	4
Length of pins for eccentric rods, inches	4 1/16
Diameter of suspension-rod pins, inches	2¾
Length of suspension-rod pins, inches	2¾
Diameter of link-block pin, inches	7
axial hole through link-block pin, inches	3
Distance between link-block jaws, inches	6

CONNECTING RODS, ECCENTRIC RODS AND ECCENTRICS.

The above mentioned rods are of open-hearth wrought steel, annealed after forging, and finished all over. The upper ends of connecting rods are forked for crosshead brasses; these brasses are of phosphor-bronze, and the crank-pin brasses are of composition lined with Parsons white metal, ⅝ inch thick. The eccentric rods are also forked to span the links, and fitted with adjustable brasses. The eccentric straps are of cast steel lined with white metal. The eccentrics are made in two parts; the larger half is of cast iron, and the smaller of cast steel.

Length of connecting rods, center to center, inches	126
Diameter of rod at crank end, inches	10
fork end, inches	8
Number of bolts in crank-pin brasses	2
crosshead brasses	4
Diameter of bolts in crank-pin brasses, inches	$4\frac{3}{16}$
crosshead brasses, inches	$3\frac{3}{16}$
Length of eccentric rods, center to center, inches	117
Diameter of eccentric rods at top, inches	$3\frac{1}{2}$
bottom, inches	$4\frac{1}{2}$
Number of bolts in top brasses, each rod	4
Diameter of bolts in top brasses, inches	$1\frac{1}{2}$
Width of eccentric straps, inches	6
Diameter of bolts in eccentric straps, inches	$2\frac{3}{16}$
studs in top of eccentric straps, inches	$2\frac{1}{2}$
eccentrics, inches	$32\frac{1}{2}$
bolts in eccentrics, inches	$2\frac{1}{2}$

CROSSHEAD GUIDES, CROSSHEADS AND CROSSHEAD SLIPPERS.

The crosshead guides are of the slipper type, of cast iron and bolted to housings, and are hollow for water circulation. The crosshead slippers are of cast steel, bolted to crossheads and filled with white metal. The crossheads are of wrought steel.

Diameter of crosshead pins, inches	10
Length of crosshead pins, each, inches	11
slipper, inches	30
Width of crosshead slipper, inches	24
Length of backing surface, inches	30
Width of backing surface, inches	16

CRANK SHAFTS.

The crank shafts are of the built-up type, each in three duplicate and interchangeable sections, and the sequence of cranks is as follows: H.P., M.P. and L.P.

Length of each section, inches	$125\frac{1}{2}$
Diameter of shafts and pin, inches	18
axial hole through shafts and pin, inches	8
Distance between crank webs, inches	20
Diameter of coupling flanges, inches	$31\frac{1}{2}$
Width of coupling flanges, inches	$4\frac{1}{2}$
Number of coupling bolts	9
Diameter of coupling bolts, inches	*3-$3\frac{1}{2}$

*Taper in 9 inches.

Diameter of crank webs, at ends, inches	37½
Thickness of crank webs, inches	12½
Number of main bearings	6
Length of main bearings, inches	18
Number of main bearing bolts per bearing	2
Diameter of main bearing bolts, inches	3 7/8

SHAFTING AND THRUST BEARING.

All shafts, except crank webs, are of high-grade carbon steel, oil tempered; tensile strength, 75,000 to 85,000 pounds; elastic limit, not less than 45,000 pounds; elongation, 24 per cent. in 2 inches.

Crank webs, tensile strength, 58,000 to 65,000 pounds; elastic limit, not less than 35,000 pounds; elongation, 25 per cent. in 2 inches; annealed after forging.

The shafting is installed in the following order: Aft of each crank shaft, thrust shaft, forward Verity coupling shaft, six lengths of line shafts, after Verity coupling shaft and the propeller shaft. The propeller shafts are encased in composition casings the whole length of stern tube.

The thrust bearing is of the horseshoe type. The body is of cast iron, so shaped that it forms a reservoir for oil with a bearing at each end.

The thrust shoes are of cast steel, hollow for water circulation, and faced with white metal.

DATA FOR SHAFTING.

Diameter of thrust shaft, inches	18
thrust-shaft hole, inches	8
Number of thrust-shaft collars	9
Outside diameter of thrust-shaft collar, inches	27½
Width of thrust-shaft collars, inches	2½
Space between thrust-shaft collars, inches	5½
Length of thrust-shaft, feet and inches	14– 5½
bearings, each, inches	15½
Number of thrust shoes	9
Diameter of thrust-bearing side rods, inches	3½
Verity coupling shafts, inches	17
shaft hole	7½
Length of Verity coupling shafts, feet and inches	7– 7½
Diameter of line shafts, inches	17
Lengths of line shafts, feet and inches	22– 6

Length of spring bearings, inches	18
Number of spring bearings in each tunnel, aft of thrust recess	14
Diameter of propeller shafts, inches	19
shaft hole, inches	8½
Length of propeller shafts, feet and inches	36–10½
Thickness of casing at bearings, inches	1¼
Length of stern bush bearing, inches	80
bearing in stern-tube stuffing box, inches	50

All shaft couplings forming part of Verity coupling, of which there are two on each line of shafting, one at after end of thrust shaft and one at forward end of propeller shaft, are 34 inches in diameter. All other shaft couplings are the same as on crank shaft.

REVERSING ENGINES.

The reversing engine is located forward of L.P. housing, with its steam cylinder bolted to same. There is an oil-control cylinder connected to the steam cylinder by tie rods, which serve as crosshead guides. One piston rod extends through each cylinder and is made of forged steel. There is also provided an oil pump, for hand reversing, of the single-acting plunger type.

The reverse shaft is near the top of the inboard side of the housings and the levers are connected to the crosshead of the reverse engine by two forged-steel connecting rods. Differential levers control the valve mechanism.

DATA FOR ENGINE.

Diameter of steam cylinder, inches	14
oil cylinder, inches	7
steam and oil piston rods, inches	3½
tail rod, inches	3½
Stroke, inches	27
Length of crosshead bearing, inches	7
Diameter of crosshead pins, inches	3½
Length of crosshead pins, each, inches	3½
Diameter of tie rods between cylinders, inches	2¾
forming crosshead guides, inches	3
threads at ends, inches	2¾
connecting rods, ends, inches	3
middle, inches	3½
Length of connecting rods, inches	82
lever on reverse shaft, inches	27

Diameter of pins in reverse lever, inches	3½
Length of reverse-shaft levers, inches	27
suspension rods to links, inches	63½
Diameter of reverse shaft, inches	8
at bearings, inches	9
Length of reverse shaft bearings, inches	10

TURNING ENGINE.

The turning engine is a double-cylinder vertical engine, operated by a change valve and located in port engine room close to bulkhead on frame No. 82. At each end of the crank is a clutch fitting into corresponding clutches on athwartship shafts, extending over to each of the main engines. These clutches are so arranged and operated by hand levers that only one main engine can be turned at a time. This athwartship shaft drives a worm and wheel (ratio, 30:1) at each main engine, this latter wheel being keyed on a vertical shaft with worm on upper end, which worm meshes into the turning wheel on after crank-shaft coupling of main engines. (Ratio of last worm and wheel, 60:1.)

DATA OF TURNING GEAR.

Number of steam cylinders	2
Diameter of steam cylinders, inches	6
piston rods, inches	$1\frac{9}{16}$
valves, inches	3
change valves, inches	3
Stroke, inches	6
Valve travel, inches	1¼
Crank angle, degrees	90
Diameter of crank shaft, inches	2½
Length of crank-shaft bearings, inches	2¾
Diameter pitch circle of horizontal worm, inches	3.66
wheel, inches	16.71
Number of teeth in wheel	30
Diameter pitch circle of vertical worm, inches	9
wheel, inches	57.3
Number of teeth	60
Diameter of vertical shaft at worm, inches	4
bearing, inches	5¼
Depth of bearing in vertical bracket, inches	19

WATER AND OIL SERVICE.

The water-service pipe is connected to a nozzle on the main circulating-pump discharge to main condensers. This pipe

leads below the floor plates to the outboard side of housings, with connections to all main bearings and guides, as well as sprays for external cooling of main bearings and crank pins. There is an extension from the water-service pipe to the thrust bearing, spring bearings and stern-tube stuffing boxes.

The oiling is by wick feed from brass oil boxes on cylinders for main moving parts; separate boxes being fitted for each main bearing and eccentrics, while eccentric-rod pins, links, etc., have separate boxes of locomotive type.

PROPELLERS.

The propeller hubs are of cast steel, fitted on the tapered end of the propeller shaft, and held in place by one longitudinal key and a nut on end of shaft, threaded in the opposite direction to the rotation of the propeller.

The blades are of maganese-bronze, and are fitted into recesses in the hub, and are held in place by steel stud bolts with composition box nuts.

The starboard propeller is right-handed and the port propeller is left-handed.

DATA FOR ONE PROPELLER.

Number of blades	3
Pitch on official speed trial, true screw, feet	22
maximum, feet	23
minimum, feet	21
Helicoidal area, square feet	97
Projected area, square feet	82
Number of stud bolts for blades	27
Diameter of stud bolts, inches	3¼
Width of longitudinal key, inches	4½
Thickness of longitudinal key, inches	2¼
Diameter of nut threads on shaft, inches	13
Length of nut threads on shaft, inches	12
Number of threads per inch	2½

MAIN CONDENSER.

One main condenser is located on the outboard side of each engine room. The shell plating is of steel and the water-heads of cast-iron, the after chest being the one for the entrance and exit of circulating water, entering at bottom and leaving

at top. Each head has four manholes, 18 inches in diameter, fitted with cast-iron covers. The condenser tube sheets are of rolled composition, with smoothly-finished holes for the tubes, tapped and fitted with composition screw glands for packing the tubes.

DATA FOR ONE CONDENSER.

Outside diameter of shell, feet and inches	6- 8¾
Thickness of shell, inch	7/16
Length of shell, feet and inches	12- 0
Thickness of composition tube sheets, inches	1½
supporting plate, inch	⅝
Number of tubes	2,456
Diameter of tubes, inch	⅝
Thickness of tubes, B.W.G	17
Length of tubes, feet and inches	12- 2
Pitch of tubes, inches	1 5/16
Cooling surface, square feet	6,750

AUXILIARY CONDENSER.

There is one auxiliary condenser in each engine room, located on the outboard side of the hot well, and mounted on a Blake horizontal combined air and circulating pumps of the well-known Wheeler type. The air pump discharges into the filter-tank on top of hotwell; the circulating pump draws from the sea, and discharges through condenser to the overboard delivery.

DATA AUXILIARY CONDENSER.

Cooling surface of one condenser, square feet	850
Diameter of steam cylinder, inches	12
air cylinder, inches	14
water cylinder, inches	14
Stroke, inches	12

MAIN CIRCULATING PUMP.

There is one centrifugal circulating pump in each engine room, driven by a two-cylinder compound vertical inverted engine, located at the after end of main condenser. Each pump draws from the sea and the engine-room bilge, and discharges through the condenser to the overboard delivery. The casing and impeller are of composition.

DATA FOR PUMP.

Diameter of suction nozzle, inches	20
discharge nozzle, inches	20
impeller, inches	42
Width at tip of blade, inches	3½
Diameter of H.P. cylinder, inches	10
L.P. cylinder, inches	20
piston rod, inches	2½
Stroke, inches	10
Length of connecting rod, inches	25
Valve travel, inches	2½
Diameter of H.P. piston valve, inches	5½
L.P. piston valve, inches	7½
crosshead pin, inches	3
Length of crosshead pin, inches	4
Diameter of crank pin, inches	4½
Length of crank pin, inches	6½
Diameter of crank shaft, inches	4½
Crank angle, degrees	90
Rate of discharge, in gallons per minute, at 160 revolvtions	10,000

MAIN AIR PUMP.

There is one Blake air pump in each engine room, located on the inboard side of the main condenser, of the vertical simplex cross-connected featherweight pattern, arranged to run both sides together or either side alone. The air cylinders are arranged with discharge valves at each end, but with no suction or bucket valves at all. Around the middle of each cylinder is an annular port connecting with the suction pipe. The passage of the air piston over this port performs the function of a suction valve.

The air pumps discharge into the filter above hotwell. When cleaning the filter, the connections are such that the air pump can discharge direct into the hotwell.

DATA FOR AIR PUMP.

Number of steam cylinders	2
Diameter of steam cylinders, inches	10
Number of pump cylinders	2
Diameter of pump cylinders, inches	20
Stroke, inches	16
Diameter of suction pipe, inches	12
discharge pipe, inches	10

HOTWELL AND FILTER TANK.

There is one hotwell in each engine room, located forward of the main air pump. The top of the hotwell is arranged as a filter; the filtering material on speed trial was hay, but was changed to "loofa," in New York, before leaving for the Pacific coast. The filtering chamber is divided by vertical partitions so that the water flows from the bottom of one to the top of the succeeding one. Each compartment in the filter tank is provided with a vapor pipe.

MAIN FEED LIFT PUMP.

There is one Blake lift pump in each engine room, located on the working platform forward of hotwell, of the vertical simplex piston type, with suctions from hotwell and reserve-feed tank and discharges into the jet feed-water heater located on the outboard engine-room casing, between lower and 'tween decks. This pump is operated automatically by a float in hotwell connected to a Fitts chronometer governor valve. Before the feed water reaches the heater it goes through a Rankin grease extractor, in which Turkish toweling is used for filtering material, drawn over perforated brass tubes.

Diameter of steam cylinder, inches	8
water cylinder, inches	12
Stroke, inches	12

MAIN FEED PUMP.

There is one Blake main feed pump in each engine room of the vertical simplex piston type, located on the working platform at side of vessel near forward end of engine room, with suctions from jet heater, hotwell and reserve-feed tank, and discharges into the main feed line, which is 5 inches in diameter. Before the feed water reaches the boilers from this pump it passes through another grease extractor of the Railton & Campbell pattern, in which Turkish toweling is also used for filtering material, in one piece, drawn over a large corrugated brass tube in each filter. This pump is operated automatically by a governor valve connected to a float in the jet

heater receiver; it can also be operated automatically from the float in the hotwell.

Diameter of steam cylinder, inches	18
water cylinder, inches	10
Stroke, inches	18
Rate of discharge, in gallons per minute, at 32 double strokes, against a water pressure of 325 pounds per square inch and a steam pressure of 125 pounds per square inch	400

AUXILIARY-FEED PUMP.

There is one Blake auxiliary feed pump in each after fire room, located at the side of the vessel, of the vertical compound duplex piston type, with suctions from jet heater, hot well, reserve-feed tank in double bottom under engine room, and the sea, and discharges into main and auxiliary-feed lines to all main boilers, and can also be used for operating the ash ejectors in fire rooms.

Diameter of H.P. steam cylinders, inches	12
L.P. steam cylinders, inches	18½
double-acting water cylinder, inches	8

GENERAL DONKEY PUMP.

There is one general donkey pump on the vessel, located in the port engine room on the orlop deck platform, close to bulkhead on frame No. 82, on the outboard side of the main engine. This pump is also of the Blake make, of the horizontal compound duplex type, with suctions from sea, all ballast tanks and bilge distribution valve boxes, with special connections to forward and after peak tanks, reserve-feed tank and port engine-room bilge, and discharges overboard, through port main condenser, into deck fire and service pipes, into main-feed line on port side, and into reserve-feed tank for filling purposes.

Diameter of high-pressure cylinders, inches	14
low-pressure cylinders, inches	20
double-acting water cylinder, inches	10
Stroke, inches	12

FIRE PUMP.

There is one fire pump on the vessel, located in the starboard engine room, on orlop-deck platform, close to bulkhead

on frame No. 82. This pump is of the Blake horizontal compound duplex piston type, with suctions from sea, ballast and bilge distributing valve boxes, with independent suction from starboard engine-room bilge, and discharges overboard, through starboard main condenser and into deck fire and service pipes.

Diameter H.P. cylinders, inches	14
L.P. cylinders, inches	20
of double-acting water cylinders, inches	10
Stroke, inches	12
Rate of discharge, in gallons per minute, at 30 double strokes, against a water pressure of 100 pounds per square inch and a steam pressure of 115 pounds per square inch	1,450

BALLAST PUMP.

There is in each engine room, under main condenser, a ballast pump of the Blake horizontal compound duplex piston type, with suctions from sea, all ballast and bilge distributing valve boxes, with independent suction from engine-room bilge, and discharges overboard and through main condenser. Pump on port side also discharges into the deck, fire and service pipes.

Diameter of H.P. cylinders, inches	8
L.P. cylinders, inches	12
of double-acting water cylinders, inches	14
Stroke, inches	18

BOILER TEST PUMP.

In the forward end of port engine room, on the working platform, close to longitudinal bulkhead, is located a Blake horizontal duplex piston pump with suctions from reserve-feed tank and all fresh-water tanks, and discharges into cross pipe connecting the two main-feed lines, and into reserve-feed tank for filling purposes. This pump is also used as a feed pump, and is large enough for feeding two main boilers, when used as donkey boilers, with a steam pressure of 200 pounds per square inch.

Diameter of steam cylinders, inches	6
water cylinders, inches	2¾
Stroke, inches	6
Rate of discharge, in gallons per minute, at 53 double strokes with 140 pounds of steam against a water pressure of 500 pounds per square inch	9

SANITARY SYSTEM.

The sanitary arrangement is on the pressure system; each of the sanitary pumps has an automatic governor valve, regulating the water pressure throughout the vessel. There is a hot, as well as a cold, water service, both for fresh and salt water, with separate pumps and distributing pipes. The sanitary pumps are of the Blake make, and are located in the port engine room, on orlop-deck platform alongside of longitudinal bulkhead.

The salt-water sanitary pump is a horizontal compound duplex pump, with suction from sea, and discharges into the salt-water system.

Diameter of H.P. steam cylinders, inches	8
L.P. steam cylinders, inches	12
double-acting water cylinder, inches	10½
Stroke, inches	10
Rate of discharge, in gallons per minute, at 78 double strokes, with a steam pressure of 140 pounds per square inch against a water pressure of 60 pounds per square inch	1,140

The fresh-water sanitary pump is a vertical compound duplex piston pump, with suction from reserve feed tank, all other fresh-water tanks and the aerating tank, and discharges into the fresh-water system.

Diameter of H.P. steam cylinders, inches	5¼
L.P. steam cylinders, inches	7½
double-acting water cylinder, inches	7½
Stroke, inches	6
Rate of discharge, in gallons per minute, at 45 double strokes with a steam pressure of 130 pounds per square inch against a water pressure of 45 pounds per square inch	390

The auxiliary sanitary pump is a horizontal duplex piston pump, with suctions from sea, reserve-feed tank, all other fresh-water tanks and the aerating tank, and discharges into both fresh and salt-water systems.

Diameter of steam cylinders, inches	10
water cylinders, inches	10¼
Stroke, inches	10

The fresh-water lift pump is a vertical simplex piston pump, with suctions from distiller air pump discharge in reserve feed tank and the other fresh-water tanks, and discharges through filters into aerating tank.

Diameter of steam cylinder, inches	4½
water cylinder, inches	6
Stroke, inches	6
Rate of discharge, in gallons per minute, at 100 double strokes, with 125 pounds of steam against a water pressure of 5 pounds per square inch	150

The fresh-water filters, aerating tank and air compressor are located on lower-deck platform, above sanitary pump. Charcoal is used as filtering material in these filters.

The air compressor is of the Blake single-flywheel type, with suction leading from boat deck, and discharges into the aerating tank through a number of holes in perforated pipes at bottom of same, the distilled water entering the aerating tank at top in form of a spray.

Diameter of steam cylinder, inches	6
air cylinder, inches	6
Stroke, inches	7

The discharge from this air compressor also leads into engine rooms, machine shop and fire rooms, with hose connections at different places for use in operating pneumatic tools, and for cleaning boiler and heater tubes, if it should be required.

EVAPORATING PLANT.

The evaporating plant is arranged with four horizontal evaporators, two distillers mounted on a combined air and circulating pump, two vertical feed-water heaters and two horizontal combined feed and brine pumps.

All of the above-mentioned machinery is located in the forward end of the engine rooms, under the orlop-deck platform, with two evaporators in each engine room.

Each evaporator receives steam from the auxiliary steam line, at a pressure of 150 pounds per square inch. The passage

of the steam is from the front to the back header through all the tubes except the bottom row, through which it is returned to the front header. Steam gague, relief valve and drain connection are made to the front header. A trap, which discharges to the reserve feed tank below, is provided to drain the tubes in each evaporator. The connections are so arranged that the evaporators can be operated single, double, triple and quadruple effect.

DATA FOR EVAPORATORS.

Diameter of shell, inches	63
Length of shell, inches	70
Thickness of shell, inch	$\frac{5}{8}$
heads, inch	$\frac{1}{2}$
Number of units to each evaporator	2
tubes in each unit	35
Diameter of brass tubes, inches	2
Thickness of brass tubes, B.W.G	10
Heating surface (tubes only) in each evaporator, square feet	225
tube sheet and header, each evaporator, square feet	13
total, each evaporator, square feet	238
Capacity of evaporators based on a four-hour test:	
Gallons of water evaporated in 24 hours, the four evaporators working single effect	52,524
When this test commenced the evaporators were perfectly clean.	
Gallons of water evaporated in 24 hours, the four evaporators working double effect	28,170
When this test commenced the evaporators had been in use four hours without being cleaned.	
Gallons of water evaporated in 24 hours, three of the evaporators working triple effect	16,824
When this test commenced the evaporators had been in use for eight hours without being cleaned.	

DISTILLERS.

The distillers are of the Wheeler Admiralty type, each mounted on a combined air and circulating pump, located on the outboard side of evaporators, one in each engine room. The bodies are of cast iron and the cooling surface is obtained from brass tubes, tinned inside and out, expanded into brass tube sheets.

Cooling surface (tubes only) in one condenser, square feet	50

COMBINED AIR AND CIRCULATING PUMPS.

The air pump discharges into fresh-water lift-pump suction box in the reserve-feed tank and into center tank No. 6 in double bottom. The circulating pump takes water from sea and discharges through distiller overboard.

Diameter of pump steam cylinder, inches	6
air cylinder, inches	8
of water cylinder, inches	8
Stroke, inches	7

EVAPORATOR FEED AND BRINE PUMPS.

The evaporator feed and brine pumps are of the Blake horizontal combined simplex type. The feed pump, with suction from distiller circulating pump discharge, discharges through the vertical feed-water heater into evaporator shells. The brine pump, with suction from bottom of evaporator shells, discharges overboard.

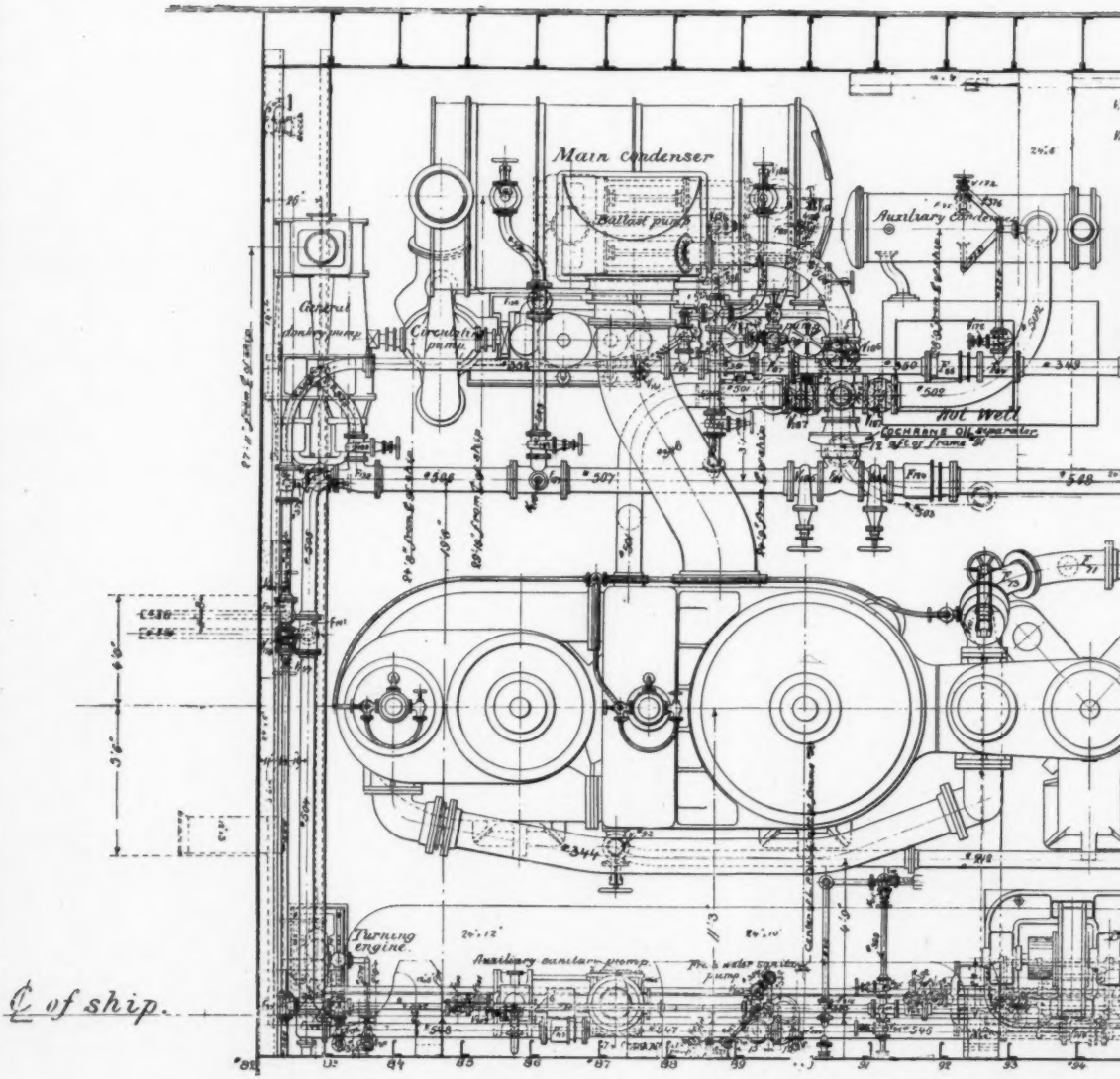
Heating surface of evaporator feed-water heater, square feet	50
Diameter of steam cylinder, inches	4½
feed-pump cylinder, inches	3½
brine-pump cylinder, inches	3½
Stroke, inches	6

MAIN BOILERS.

There are sixteen Niclausse water-tube boilers, designed and built by the Stirling Company, for a maximum coal consumption of 40 pounds per square foot of grate surface per hour, containing 272 elements, constructed for a steam pressure of 250 pounds and arranged fore-and-aft as shown on plate No. 1.

Each boiler is fitted with a horizontal air-heating tube box on top of casing and at back of drum to heat the air before entering the ash pit in connection with the Ellis and Eaves' system of induced draft.

When the fires are worked under the induced-draft system, the air necessary for combustion enters one section of the heater tubes at one end of box and enters the other section at end of box diagonally opposite; that is, that the air travels through one section of heater tubes in one direction, while in


Main condenser
Ballast pump
Auxiliary Condenser
General service pump
Circulating pump
Hot Well
Cochrane Oil separator
Turning engine
Auxiliary sanitary pump
℄ of ship.

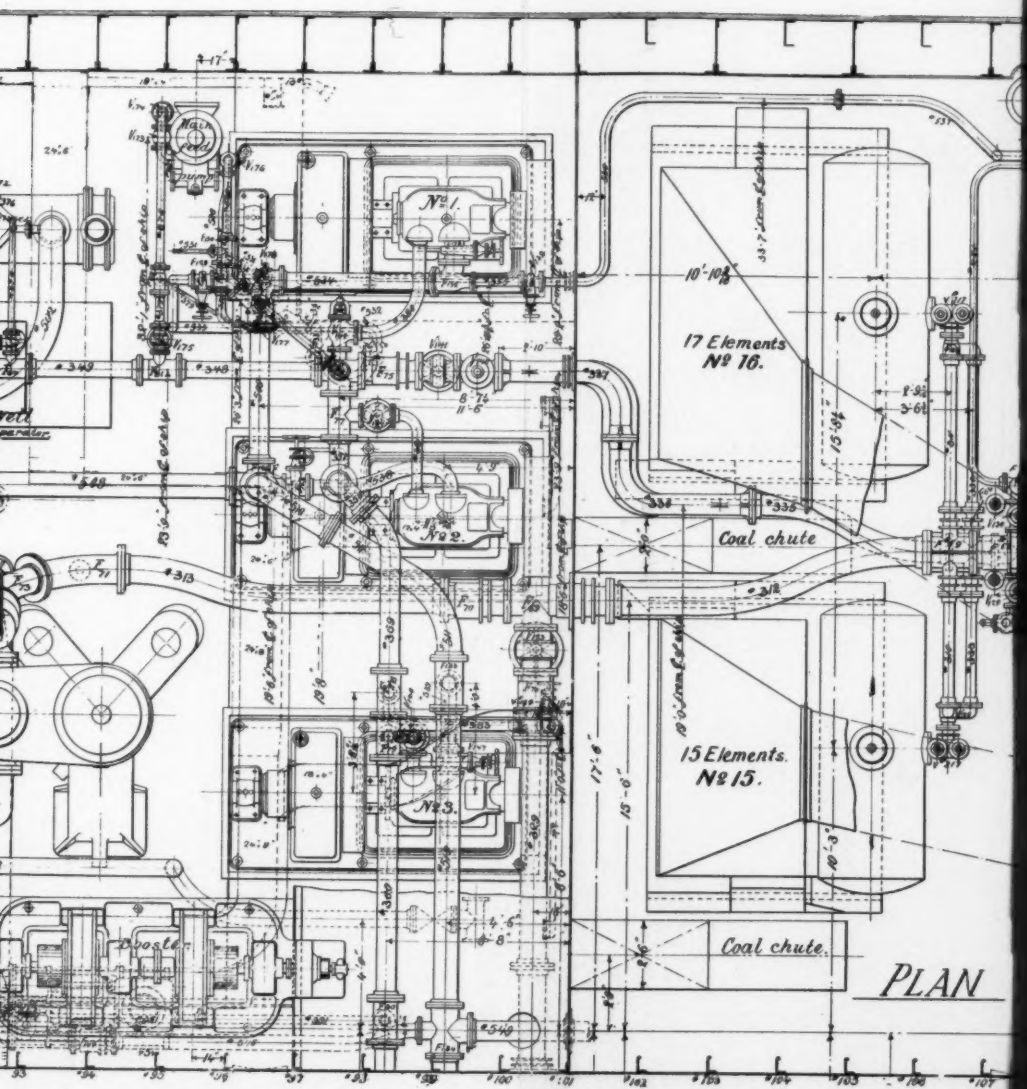


Plate I.

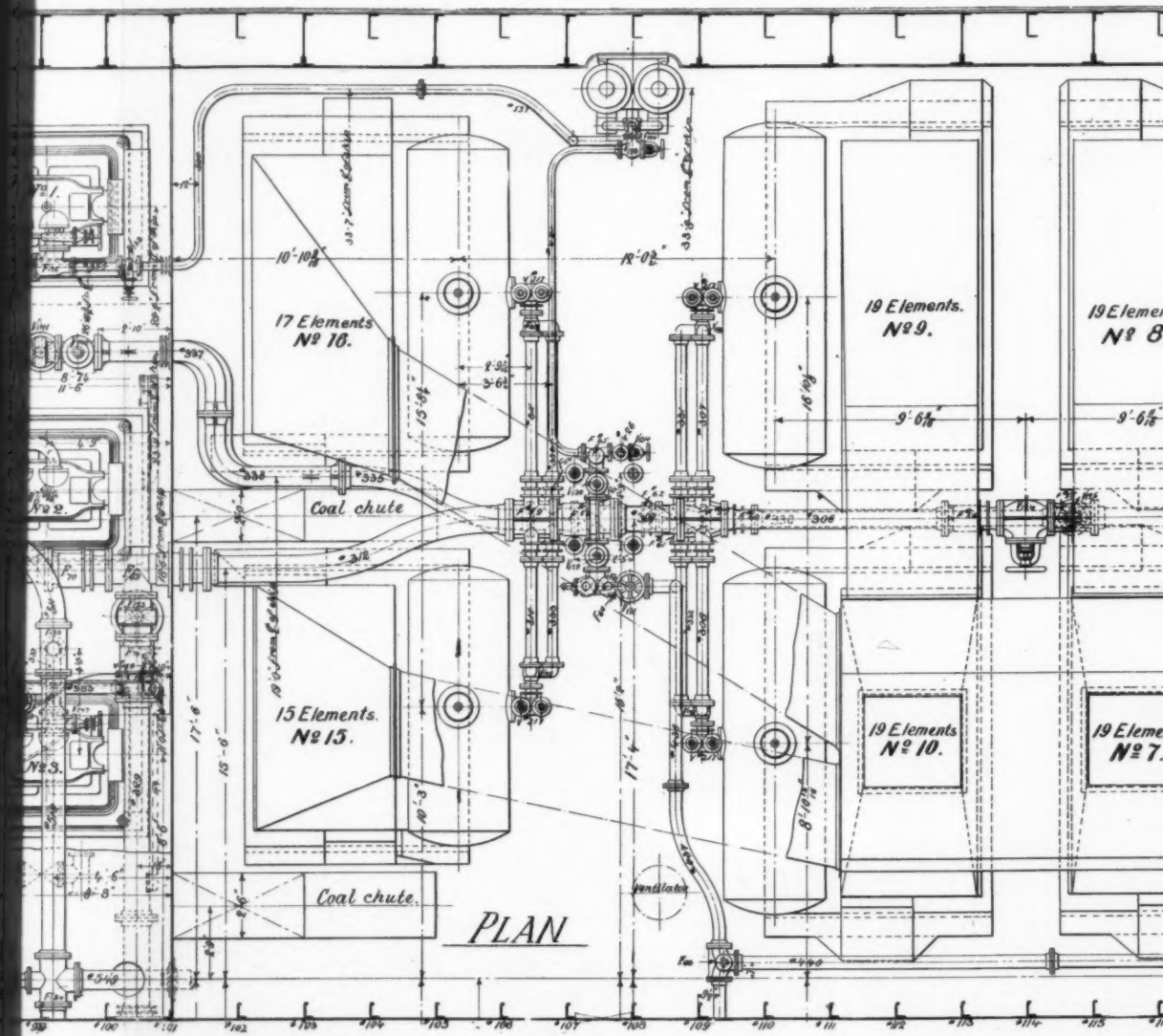
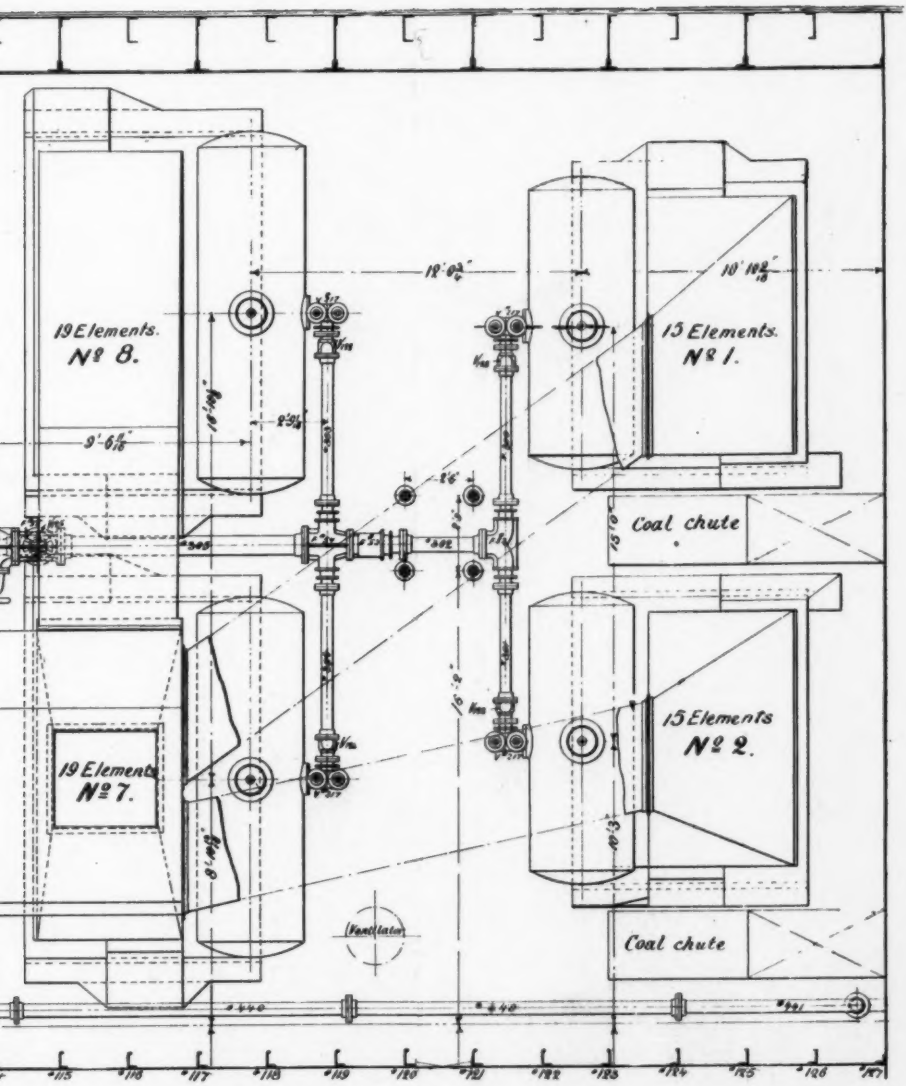

17 Elements
№ 16.
19 Elements.
№ 9.
19 Elements
№ 8
Coal chute
15 Elements.
№ 15.
19 Elements
№ 10.
19 Elements
№ 7.
Coal chute.
PLAN

Plate I.


19 Elements.
№ 8.
19 Elements.
№ 7.
15 Elements.
№ 1.
15 Elements
№ 2.
Coal chute
Coal chute
Ventilator
18'-0½"
10'-10½"
9'-6⅛"
15'-10"
10'-8"
2'-6"
115
116
117
118
119
120
121
122
123
124
125
126
127

the other section of tubes it travels in the opposite direction, thence down at both sides of boiler casing through passages into ash pits. These passageways, forming part of the boiler side casing, are insulated and gradually widen out to the full length of ash pit at bottom. (See Fig. 3.)

DATA FOR BOILERS.

Number of boilers, including all sizes....	16			
	15 element.	17 element.	18 element.	19 element.
Number of boilers in reference to number of elements	6	2	4	4
Number of tubes in each element	24	24	24	24
Diameter of steam drum inside, inches	45	45	45	45
Length steam drum, feet and inches	9- 7 1/2	10-10 1/4	11- 5 1/2	12- 3/4
Thickness of drum plate, inches	1 5/16	1 5/16	1 5/16	1 5/16
Diameter steam dome, inches	11 29/32	11 29/32	11 29/32	11 29/32
Height steam dome, inches	16	16	16	16
Size rectangular section of headers, ins	6 7/8 × 7 3/32 × 7/16 inch thick.			
Diameter evaporating tubes, inches	3 1/4	3 1/4	3 1/4	3 1/4
Length evaporating tubes, feet and ins	7- 4 1/2	7- 4 1/2	7- 4 1/2	7- 4 1/2
Thickness evaporating tubes in the eight lower rows, B.W.G.	6	6	6	6
Thickness evaporating tubes above the eighth row, B.W.G	8	8	8	8
Diameter of circulating tubes, inches	1 19/32	1 19/32	1 19/32	1 19/32
Length of circulating tubes, ft. and in	7- 3 1/16	7- 3 1/16	7- 3 1/16	7- 3 1/16
Thickness of circulating tubes, B.W.G	21	21	21	21
Total heating surface, square feet	13,438	5,077	10,751	11,348
Total heating surface in all boilers, sq. ft.	40,614			
Grate surface in boilers for hand firing, square feet	298	67.5	143	301
Grate surface in boilers with stokers, square feet	59	67.5	152	
Total grate surface, square feet	357	135	295	301
Total grate surface, all boilers, sq. feet	1,088			
Ratio of H.S. to G.S.	37.3 : 1			
Diameter tubes in heater boxes, inches	3	3	3	3
Thickness tubes in heater boxes, B.W.G.	12	12	12	12
Length tubes in heater boxes, ft. and in.	3-10 1/4	4- 6	4- 9 1/4	5- 1 1/4
Total number tubes in heater boxes	2,160	776	1,680	1,680
Sectional area of heater tubes for one boiler, square feet	7.597	8.186	8.863	8.863
Sectional area of space between heater tubes for escape of waste gases in each boiler, square feet	10.83	12.54	13.4	14.44
Sectional area of uptake for each boiler	10.5	11.5	12.5	13
Total sectional area of all branch uptakes, square feet	188			
Sectional area of the four main uptakes, square feet	182			
Sectional area of rectangular stack above upper deck, square feet	224			
The smokestack is double and elliptical in shape.				
Outer stack, 19 feet fore-and-aft and 16 feet 3 inches athwartship.				
Inner stack, 16 feet fore-and-aft and 13 feet 6 inches athwartship.				
Height of stack above base, feet and inches	134- 6			
grate, feet and inches	124-10			
boat deck, feet and inches	54- 6			

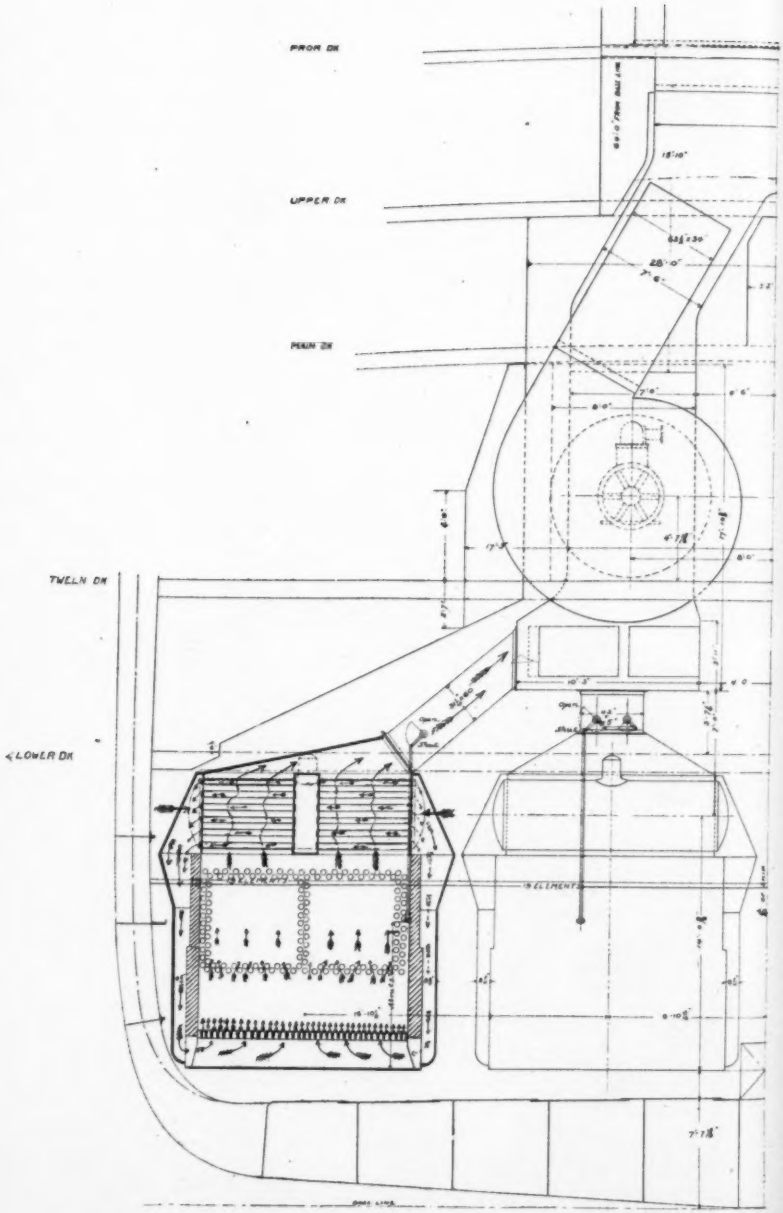


Fig. 3.

It will be understood that the air is heated while passing through the horizontal tubes on top of boiler by the gases from the fire below, passing on the outside of said tubes before entering into the uptake.

Provision is made on each boiler for letting in and regulating the air supply, from the side passages to top of grate at front and back of fires.

The air passages at side of boilers are fitted with dampers which are operated from the front of boilers. The main uptake on each side of the vessel is divided by a center partition up to the main deck, in which are fitted two large dampers for changing the condition of draft from natural to induced, or *vice-versa*. Each branch uptake is also fitted with a damper which is operated from the fire-room floor.

The four after starboard boilers are fitted with Duluth mechanical stokers, driven by two 7-inch × 6-inch vertical inverted engines, located on the starboard side of longitudinal bulkhead in about the middle of after fire room on level with the orlop-deck grating.

INDUCED-DRAFT FANS.

There are four induced-draft fans, two on each side, located forward and aft of the main uptakes, between main and 'tween-deck gratings. These fans are manufactured by the New York Blower Co.: each of them is direct connected to a Westinghouse automatic compound engine, located in recesses forward and aft of boiler-hatch casings, as will be seen on Fig. 3.

Diameter of fans, inches	108
Width at tip of blades, inches	30
Area of inlet, square feet	30
outlet, square feet	19.25
Diameter of H.P. cylinder, inches	9
L.P. cylinder, inches	15
Stroke, inches	9

STEAM AND EXHAUST PIPES.

The arrangement of steam and exhaust pipes is about the same on both sides, with the exception of steam and exhaust.

pipes to sanitary pumps, which are in the port engine room. The port and starboard main steam lines and the auxiliary steam and exhaust lines are connected in the engine rooms by cross-pipes. There is on each auxiliary steam line an 8-inch Leslie reducing valve, located at forward end of engine room, reducing the boiler pressure to 150 pounds per square inch. On the branch castings on auxiliary steam lines in the after fire rooms are four reducing valves, connected for reducing the boiler pressure to 150 pounds per square inch for steam pipes leading to windlass engines, induced-draft fan engines, auxiliary feed pumps, chain-grate engines, and ash-hoist engines.

From the above mentioned arrangement of reducing valves, it will be understood that all of the auxiliary machinery is supposed to work with a steam pressure of 150 pounds per square inch, but all of them are so constructed that they will stand the full boiler pressure in case the reducing valves should fail to do their duties.

The main steam pipe and auxiliary steam pipe are the same for the eight forward boilers; but, for the eight after boilers these pipes are separate and parallel.

The exhaust steam from all auxiliaries goes through two Cochrane vacuum oil separators before entering the pipes leading to main condensers, auxiliary condensers, jet heaters, and the low-pressure receivers. These separators are located under lower deck in the engine rooms, one on each side above main air pumps.

The diameter of main steam pipes is 11 inches, and the diameter of steam pipe from each of the main boilers is 4 inches. The auxiliary steam pipes are eight inches in diameter, and the steam exhaust pipes are 10 inches in diameter.

All pipes subject to a steam pressure of 250 pounds per square inch are solid-drawn steel pipes, with fittings and flanges of crucible steel. All auxiliary steam pipes subject to a steam pressure of 150 pounds per square inch, and all feed pipes, are of solid-drawn copper with brazing metal flanges containing 80 parts of copper and 20 parts of zinc, with the exception of steam pipes to windlass and steam-steering gear,

which are lap-welded wrought-iron pipes expanded and beaded into semi-steel flanges.

The deck fire and water-service pipes are lap-welded iron pipes, expanded and beaded into semi-steel flanges, which are faced after being secured to pipe, and then pipe and flanges are galvanized together. All steam-exhaust pipes are of solid-drawn copper, with flanges and fittings of semi-steel.

ELECTRIC PLANT.

The electric plant is located on orlop deck, at the forward end of engine rooms. It extends the full width of the vessel and is divided by the longitudinal bulkhead through which a vertical watertight door provides communication between port and starboard sides. There is installed on each side, three direct-connected Westinghouse generating sets, each of 75 kw., driven by a Westinghouse vertical compound engine. Each generator is a six-pole machine, furnishing direct current at 110 volts when making 300 revolutions per minute.

DATA FOR GENERATOR ENGINES.

Total number of engines	6
Diameter of H.P. piston, inches	11
L.P. piston, inches	19
Stroke, inches	11

The wiring is on the three-wire system, and several switchboards are conveniently placed throughout the vessel; lights take 110 volts, power and heating, 220 volts. The cables from each generator are led to the switchboards in the engine rooms and from these switchboards to a large switchboard in the central station on upper deck. Motor drive is used for the refrigerating machinery, cargo winches, ventilating fans, steering gear, laundry machinery, coal conveyor, coal elevator, provision hoist, machine shop and after warping capstans.

The electric-light installation consists of about 1,300 16-candlepower lights, distributed throughout the vessel, and a powerful 24-inch searchlight of the General Electric make, located on the forward lookout bridge. This light can be oper-

ated from the navigating bridge by an electric or hand gear. The port, starboard and masthead lights are electric, and a tell-tale is fitted in the chart house, which indicates if lights are burning or not. For signalling in fog, an electrically-operated steam whistle is installed, which is automatically sounded at desired intervals by a clock control, and can also be controlled by hand.

There are two different telephone installations: one, the general, which is a regular telephone exchange connecting the various staterooms with the steward's office; the other is a special system which connects the executive offices of the vessel with each other. The switchboard of the general system is located in a separate room on the upper deck forward of the central electric station. Besides the instruments in the staterooms, telephones are installed in almost every part of the vessel, such as the Captain's private stateroom, the ladies' boudoir, library, smoking room, barber shop, kitchen, saloon pantry, laundry, chief engineer's office and chief electrician's office, so that no matter what the passengers want they can be connected with the department desired.

REFRIGERATING PLANT.

The refrigerating plant is located on the upper deck in the forward end of forward deckhouse and extends the full width of the house. The plant consists of two 30-ton Linde marine ammonia compressors with the necessary accessories.

The space for carrying refrigerated cargo has a capacity of about 650 tons, located in lower part of hold No. 3; it is divided into several compartments which are installed with mineral wool and sheathed with wood. In addition to the above, there is a space in hold No. 5, also divided into several compartments, where ship's provisions are stored and kept at varying temperatures, from 26 degrees Fahrenheit to 40 degrees Fahrenheit. The compartments for provisions are cooled by rows of brine pipes, and the cargo spaces are cooled by cold air which is driven through ducts leading from air coolers.

There is, also, in connection with the refrigerating plant, an ice-making tank with twelve 50-pound cans and a cooling system of drinking water throughout the vessel. The whole refrigerating plant is arranged in duplicate, one compressor being able to take care of the cargo and stores. The cooling effect of one compressor is equivalent to 30 tons of ice per twenty-four hours.

DATA.

Two air compressors, each driven by a 75-H.P. motor.

Two condensers, with two centrifugal circulating pumps each driven by a 10-H.P. motor.

Two brine coolers, brine circulated by two centrifugal pumps, each driven by a 10-H.P. motor.

Two air coolers, air circulated by two air-blowing fans, to circulate 7,000 cubic feet of air per minute, each driven by a 6-H.P. motor.

The air is purified in coolers by two brine-spraying pumps, each driven by a 7½-H.P. motor.

The drinking water is circulated through the cooler by a circulating pump driven by a 3-H.P. motor.

MACHINE SHOP.

The machine shop is located on 'tween deck on the outboard side of port engine-room casing, extends the full length of same, and is entered from the engine-room 'tween-deck grating. The following machines are installed:

One Prentice Brothers 30-inch upright drill;
One Prentice Brothers 14-inch sensitive drill;
One Flather 24-inch engine lathe, with taper attachment and compound rest;
One Hendy 24-inch shaper, with adjustable swivel table;
One 12-inch Chicago emery wheel grinder;
One 30-inch × 4-inch grindstone with truing device;
One power hack saw.

These tools are provided with the requisite attachments. Lockers and tool benches are also provided. The machines are driven by a 10-H.P. motor located on bulkhead at the after end of the machine shop.

ANCHOR WINDLASS.

There is a vertical Hyde steam windlass and two warping capstans located on the upper deck forward, the engines being located on the forecastle deck below; the two vertical shafts are driven by worm gear direct from the worm on the crank shaft of the engine.

Each vertical shaft carries on its upper end, above upper deck, a wild-cat with locking gear. The arrangement is such that the wild-cats can be operated together or independently of each other. Each wild-cat is fitted with a positive locking device, worked by raised cams on the periphery of the locking rim and slotted block keys operated by means of levers. The entire operation of locking or unlocking the wild-cat is accomplished by one motion of the lever through an angle not exceeding 60 degrees. A friction-band brake is fitted to each wild-cat. Each friction band is provided with a compressor, so that either chain can be checked when running out.

The two warping heads, each about 26 inches diameter of barrel, are operated by the windlass engines through bevel and worm gearing. These warping capstans are capable of taking in rope at the rate of 10 fathoms per minute and to operate together or independently of each other. The engines are reversed by a change valve, so arranged as to be operated from both the upper and forecastle decks.

The windlass, as a whole, with 150 pounds of steam per square inch, will raise two $8\frac{1}{2}$-ton anchors with 60 fathoms of $3\frac{3}{16}$-inch chain at the rate of 5 fathoms per minute.

DATA FOR ENGINES.

Number of cylinders	2
Diameter of cylinders, inches	18
Stroke, inches	14
Diameter steam pipe, inches	5
exhaust pipe, overboard, inches	6
to condenser, inches	4

STEERING GEARS.

There is a Williamson Brothers combined steam and electric steering gear. Both are directly attached to the quadrant and

are located on the upper deck in the steering-gear house aft. The engines and motor are controlled from steering columns on upper and lower navigating bridges by the same hand-steering wheel, a hydraulic telemotor, actuating the engine valves, while the electric steering motor is controlled through the Electro Dynamic Company's steering column on the lower navigating bridge. On the lower-deck platform, near the forward end of port-engine room, close to the longitudinal bulkhead, is located a motor-driven generator (Booster) with an exciter attached to the same shaft. The fields of the exciter are in circuit with the balancing wire connecting the steering resistance with the rudder resistance. By suitable arrangement and proportions of generator and exciter, to multiply the effect of a small current flowing in the balancing wire, sufficient power is obtained to drive the rudder motor.

A pair of warping capstans are located on the upper deck, one on each side of the steering-gear house aft; they are driven by a motor located on main deck.

DATA FOR STEERING GEARS.

Number of steam cylinders	2
Diameter of steam cylinders, inches	13
Stroke, inches	10
H.P. of electric steering-gear motor	75
motor for after warping capstans	100

DOCK TRIAL AND PRELIMINARY SEA TRIAL.

The main engines and auxiliary machinery were worked under steam several times before the S. S. *Dakota* left the builders' wharf, and on March 3, 1905, the official dock trial took place. On that day the main engines were worked for eight hours, up to 60 revolutions per minute, with only four boilers on each side.

At the request of the Great Northern Steamship Company the S. S. *Dakota* was taken to sea for a 24-hour run, in order to adjust compasses and give the machinery a trial under actual conditions at sea before leaving the hands of the builders.

On the return to New London, Conn., March 24, 1905, every-

thing was opened up in engine and boiler rooms, inspected, and pronounced to be in a satisfactory condition, as the result of which the vessel was handed over to the owners.

At 1 P. M., on March 27, 1905, the S. S. *Dakota* left New London, Conn., for Newport News, Va., in charge of Mr. C. C. Lacey, the marine superintendent of the Great Northern Steamship Co., and Mr. Robert S. Paul, the chief engineer in charge of the engine and boiler rooms. The builders were represented by several gentlemen who had been in charge of the different departments during the construction and building of this vessel.

During the run to Newport News, Va., several observations were taken in connection with the machinery and boilers, particular care being taken in training the firemen to fire the water-tube boilers, and good results were obtained with a comparatively green crew of firemen, for that kind of boiler; this was due to the intelligent engineering staff, and in particular to the efforts of Mr. Andrew Bishop Cox, who represented the Stirling Company.

On this run only twelve boilers were in use, including the four boilers with mechanical stokers; the steam pressure in boilers was kept at about 200 pounds per square inch and at no time was it over 210 pounds with the induced-draft fans running from 150 to 175 revolutions per minute, the main engines making, on an average, 60 to 65 revolutions per minute.

The bottom of vessel, after being so long in the water, was naturally very foul, and the speed on that account not as it would have been with a clean bottom.

The water used on this trip for making up the boiler feed was carefully taken every hour, and was found to be on an average of 3.41 tons of 2,240 pounds per watch of four hours.

Steamship *Dakota* anchored at Hampton Roads, Va., at 12.15 A. M. on March 29th, 1905, and entered the dry dock at Newport News Shipbuilding and Drydock Co., 3 P. M. on the same day. While in the drydock the cast-steel propeller blades were taken off and manganese-bronze blades, set at a

pitch of 22 feet, were put on. The bottom was given two coats of anti-corrosive and one coat of anti-fouling paint of the Rahtjen "Red Hand" brand.

OFFICIAL SPEED TRIAL.

S. S. *Dakota* left Newport News, Va., at 5·30 P. M. on April 1st, 1905, and steamed slowly to sea. Her draught on leaving Newport News was 23 feet aft and 15 feet 8 inches forward; but, on the way to sea, some of the tanks forward of midships were filled to get her on a more even keel, and the draught on trial was 21 feet 9 inches aft and 17 feet 1 inch forward, corresponding to a displacement of about 17,000 tons.

After midnight in the early morning of April 2d, 1905, the fire was started in all the main boilers, the steam pressure increased and the main engines gradually worked up to full power.

At about 5 A. M. she was turned around and started for a straight course between Winter Quarter Shoal lightship to Cape Charles lightship, off the coast of Virginia. The wind was about 18 knots, abaft beam, the tide about slack, if anything a little in her favor, and the sea was comparatively smooth. The time for passing the above-mentioned points was taken on the bridge by Captain Emil Francke, the commander of the vessel.

Passed Winter Quarter Shoal lightship	5·37 A. M.		
Cape Charles lightship	8·57 A. M.		
Elapsed time in hours and minutes	3 hours 20 minutes.		
Distance between two points, knots	57 (about).		
Average speed in knots per hour	17.1		
	Port. Eng.	*Star. Eng.*	
Total revolutions during trial run	17,332	16,930	
mean of both engines	17,131		
Slip of propeller in per cent. of its own speed	8.049		
Maximum I.H.P. developed	6,090	5,850	
total both engines	11,940		

For further information, see accompanying tables giving results obtained on the speed-trial run.

The main engines during the trial ran smoothly with very little vibration, and none of the bearings heated. The internal water service was used in the main bearings, crosshead

guides and thrust bearings, but no water was used on any other parts.

The main boilers made all the steam the engines could use, and the safety valves were blowing off steam practically the entire run, they being set at 250 pounds pressure. The mechanical-stoker boilers seemed to do more than their share, and after the speed trial the engineers spoke of the stoker boilers as good steamers, and the prejudice against the stokers commenced to disappear.

In using the pyrometer on top of the boiler tubes in stoker boilers the temperature varied but very little for the same speed of grate, but that can not be said about the boilers fired by hand, as the temperature above boiler tubes in those boilers varied considerable, due to the opening and closing of furnace doors.

I believe, basing my statement on what I saw of the mechanical stokers of steamship *Dakota*, that the mechanical-stoker principle for firing water-tube boilers on shipboard will sometime in the future take the place of hand firing, as it has done on larger boiler plants on shore.

The smoke emitted from the funnel during the trial was light gray nearly all the time, and at no time was it very heavy. The automatic feed-regulating valves on the main boilers worked almost without attention, and there was no trouble experienced with the feeding of the main boilers.

An attempt was made to find out the coal consumption during the trial, but failed on account of incomplete arrangement being made beforehand, and what preparation there had been made failed when the time came to try the correctness of the results. The coal consumption was, however, estimated to be 1.75 pounds per I.H.P. per hour. The kind of coal used was Pocahontas.

The water used for making up the boiler feed during the speed trial of three hours and twenty minutes, according to the float in the reserve feed tank, was about 41 tons, and, although the safety valves were blowing off steam a great deal, we knew that the water consumption could not have been as large as stated above, on careful inspection by the first assistant

engineer it was found that the drains from grease extractors on the port main feed line had been left open by the man cleaning the filters the day before leaving Newport News, Va., which accounted for the great water consumption.

After the trial S. S. *Dakota* was headed for Norfolk, Va., to take on bunker coal at Lamberts Point coal piers, where she arrived at 3 P. M. on the same day.

Some trouble was experienced in coaling her on account of her great height, and it took several days to fill her bunkers with 5,226 tons of coal.

The *Dakota* left Norfolk, Va., at 10 A. M. on April 12th and arrived at the pier in New York at noon on April 13th, 1905.

In New York, while taking in a cargo of over 9,000 tons dead weight, consisting principally of steel rails, water and provisions for her long voyage, the main engine cylinders, valve chests, low-pressure valves, crank and crosshead-pin bearings, crank-shaft bearings and crosshead guides were examined and found to be in excellent condition.

In taking off the covers on main condenser heads the tube-packing glands and nuts on tube-sheet braces were found to be a little loose. They were all set up and tested for tightness. The main air pumps and main feed pumps were also opened up and found fairly free from grease and in good condition.

All the manhole covers on steam drums of main boilers were taken off, drums examined, and there was no sign of any grease in same, with the exception of in boilers Nos. 1 and 2, which had been used as donkey boilers at Norfolk, Va.; in these was found a very light coat of grease at the water line. Several tubes were taken out in the different boilers, examined and found free from grease and in good condition. No difficulty was encountered in removing the tubes.

Steamship *Dakota* left New York at 1·30 P. M. on April 28th, 1905, drawing 32 feet aft and 31 feet 6 inches forward. The first stop is supposed to be Coronel, Chili, and I know of no reason why she should not make a creditable showing on the run to Seattle, Washington.

RESULTS OF SPEED TRIAL OF S. S. *DAKOTA*.

Date, April 2, 1905. **Table No. 1.** Eastern Shipbuilding Co., New London, Conn.

Time.		Opening of throttle.		Position of main valve links.		Readings of counter.		Revolutions per minute.		Steam pressure per square inch (above atmosphere).								Vacuum.	
										Main steam at throttle.		H.P. steam chest.		M.P. receiver.		L.P. receiver.		Auxiliary steam.		Main condenser.	
P.	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P*	*S.*	*P.*	*S.*	*P.*	*S.*
A.M.	A.M.	*Inches.*	*Inches.*															*Inch.*	*Inch.*	*Inch*	*Inch.*
5.30	5.30	.66	.68	Normal: 10-inch travel of valves.	Normal: 10-inch travel of valves.	60,920	65,660	83	82	235	235	215	215	62	62	10	10	150	150	24	24
5.37	5.37	.....	.....			61,518	66,240	...	Winter quarter shoal light ship abeam.									...	...	...	...
6.00	6.00	.68	.70			.....	.....	83	82	235	235	215	215	62	62	10	10	150	150	24	24
6.30	6 30	.7	.75			.....	.....	84	83	236	236	218	218	63	63	10½	10½	150	150	23⅞	23⅞
7.00	7 00	1.	1.			.....	.....	85	84	236	236	218	218	70	71	10½	10½	150	150	23⅞	23⅞
*7.30	7.30	2.	2.			.....	.....	88	87	240	240	225	220	70	80	13	13	150	150	23	23¼
8.00	8.00	2.	2.			.....	.....	90	89	240	240	225	220	70	82	14	14	150	150	22½	23
8.30	8 30	1⅞	1⅞			.....	.....	87	86	238	238	220	220	70	82	14	14	150	150	22½	23
8.37	8 37	1⅛	1⅛			78,850	83,170	...	...	...	Cape Charles light ship abeam.							...	...	...	...
9.00	9 00	1½	1½			.....	.....	84	81	235	235	215	215	70	80	13	13	150	150	23	23¼

*M.P. and L.P. pass-over valves open during last five periods. Auxiliary condensers not used. No steam pressure in cylinder jackets during speed trial.

Table No. 2.

Time.		H.P. Cylinder.			M.P. cylinder.			L.P. Cylinder			Gauge pressures, in pounds per square inch.			
		Number of card		Scale of spring.	Number of card.		Scale of spring.	Number of card.		Scale of spring.	Jet heater.		Feed-water filter.	
P.	*S.*	*P.*	*S.*		*P.*	*S.*		*P.*	*S.*		*P.*	*S.*	*P.*	*S.*
A.M.	A.M.													
5.30	5 30	1	1	100	1	1	50	1	1	16	4	4½	265	265
6.00	6.00	2	2	100	2	2	50	2	2	16	4	4½	266	266
6 30	6.30	3	3	100	3	3	50	3	3	16	4½	5	268	270
*7 00	7.00	4	4	100	4	4	50	4	4	16	4½	5	262	263
7.30	7.30	5	5	100	5	5	50	5	5	16	4½	5½	264	265
8.00	8 00	6	6	100	6	6	40	6	6	16	5	5½	268	271
8 30	8.30	7	7	100	7	7	50	7	7	16	5½	5½	266	268
9.00	9 00	8	8	100	8	8	50	8	8	16	5½	5½	263	264

*M.P. and L.P. pass-over valves open during last five periods.

RESULTS OF SPEED TRIAL OF S. S. *DAKOTA*.

Date, April 2, 1905. Eastern Shipbuilding Co., New London, Conn.

Table No. 3.—PORT.

Time.	Steam pressure given in pounds per square inch above atmosphere. vacuum given in inches of water.																Temperature, degrees Fahrenheit.													
	Steam pressure in main boilers, pounds.								Vacuum in ash pits, inches.								After fire room.	Forward fire room.	In ash pit.						Of gases.			
	No. 1.	No. 2.	No. 7.	No. 8.	No. 9.	No. 10.	No. 15.	No. 16.	No. 1.	No. 2.	No. 7.	No. 8	No. 9	No. 10.	No. 15.	No. 16.			No. 1.	No. 2.	No. 7.	No. 8.	No. 9.	No. 10.	No. 15.	No. 16.	Above boiler tubes.	Above heater tubes.	Above boiler tubes.	Above heater tubes.
																											Blr. No. 10.		Blr. No. 16.	
A.M.																														
5 30	250	250	250	250	250	250	250	250	.25	.3	.2	.3	.25	.2	.3	.4	120	106	300	280	260	265	280	275	300	320	730	550	720	542
6.00	250	250	250	250	250	250	250	250	.3	.2	.3	.2	.2	.25	.2	.4	122	106	310	280	275	260	300	280	320	330	735	555	718	541
6 30	250	250	250	250	250	250	250	250	.2	.2	.3	.25	.1	.3	.2	.5	123	106	324	320	395	270	296	285	312	310	740	560	725	546
7.00	245	245	245	245	245	245	245	245	.25	.25	.35	.1	.2	.15	.25	.5	122	110	322	300	300	275	296	288	312	310	750	570	730	552
7.30	248	248	248	248	248	248	248	248	.3	.3	3	.2	.25	.2	.3	.5	132	115	324	320	310	285	306	290	315	315	745	560	732	552
8.00	250	250	250	250	250	250	250	250	.2	.2	.25	.25	.2	.25	.25	5	130	118	330	325	308	290	310	285	320	310	740	560	730	551
8.30	248	248	248	248	248	248	248	248	.25	.25	.3	.22	.22	.3	.3	.5	130	120	330	320	310	292	312	290	322	320	725	550	728	550
9.00	245	245	245	245	245	245	245	245	.3	.3	.35	.2	.25	.2	.25	.5	130	120	330	320	310	295	312	295	319	310	730	552	725	552

Table No. 4.—STARBOARD.

	No. 3.	No. 4.	No. 5.	No. 6.	No. 11	No. 12.	No. 13.	No. 14.	No. 3.	No. 4	No. 5.	No. 6.	No 11.	No. 12.	No. 13.	No 14.			No. 3.	No. 4.	No. 5.	No. 6.	No. 11.	No. 12.	No. 13.	No. 14.	Boiler No. 11.		Boiler No. 4.	
A.M.																														
5.30	250	250	250	250	250	250	250	250	.25	.5	.25	.25	.3	.2	.25	.25	120	96	280	290	285	290	252	210	215	225	735	555	710	535
6.00	250	250	250	250	250	250	250	250	.25	.5	.4	.25	.5	.25	.25	.25	125	96	280	290	290	270	250	215	218	230	740	560	710	535
6.30	250	250	250	250	250	250	250	250	.3	.5	.3	.25	.5	.25	.25	.25	130	98	280	300	295	272	250	215	218	232	745	566	720	540
7.00	245	245	245	245	245	245	245	245	.4	.5	.5	.25	.5	25	.25	.25	130	100	300	310	300	275	260	215	220	230	745	566	725	546
7.30	248	248	248	248	248	248	248	248	.4	.5	.5	.25	.5	.25	.25	.25	135	102	304	320	310	280	275	220	225	224	750	570	728	550
8.00	250	250	250	250	250	250	250	250	.5	.5	.5	.25	.5	.25	.25	.25	135	104	306	322	310	282	275	220	220	225	748	568	730	551
8.30	248	248	248	248	248	248	248	248	.5	.5	.4	.25	.5	.25	.25	.25	136	101	304	322	308	280	278	218	218	230	745	565	728	549
9.00	245	245	245	245	245	245	245	245	.4	.5	.3	.25	.5	.25	.25	.25	136	100	300	320	306	280	270	218	220	225	740	560	725	545

RESULTS OF SPEED TRIAL OF S. S. *DAKOTA*.

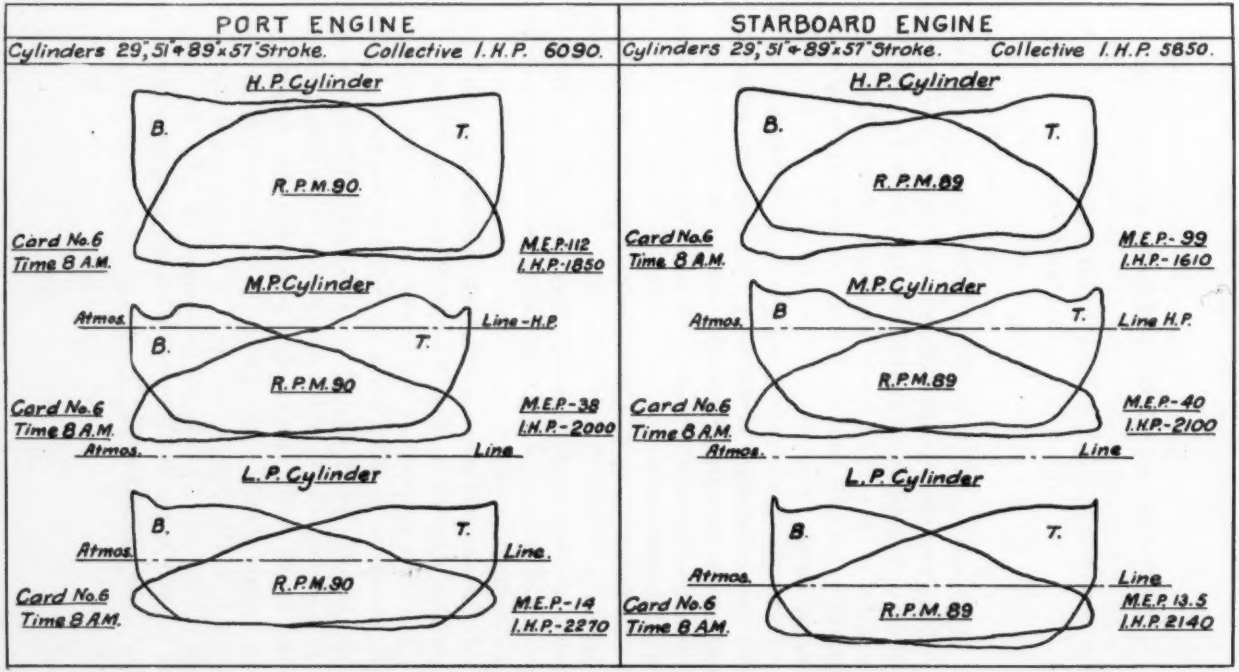
Date, April 2, 1905. Eastern Shipbuilding Co., New London, Conn.

Table No. 5.

Time.		Revolutions, or double strokes, per minute.								Temperature, degrees Fahrenheit.									
		Main circulating pump.		Air pump.		Main feed pump.		Main feed lift pump.		Auxiliary circulating and air pump.		Engine-room working plate.		Main circulating pump.				Hot wells.		Feed water leaving heater.	
														Suction.		Discharge.					
P.	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*	*P.*	*S.*
A.M.	A.M.																				
5 30	5.30	190	210	46	28	24	20	21	18	Not used during trial.	Not used during trial.	70	74	45	45	87	88	62	76	170	178
6.00	6.00	190	190	46	50	24	20	21	18			70	74	45	45	87	88	62	76	170	178
6.30	6.30	187	190	46	50	24	20	21	18			70	74	45	45	87	88	62	76	180	182
7.00	7.00	187	190	46	24	26	20	21	20			70	74	45	45	87	88	62	76	182	183
7.30	7.30	185	185	44	24	24	19	21	19			71	75	46	45	87	90	62	78	182	188
8.00	8.00	184	185	44	26	26	28	20	20			72	76	45	45	93	97	66	85	192	195
8.30	8.30	184	185	44	26	26	28	20	20			72	76	45	45	93	98	66	86	198	200
9.00	9.00	190	185	44	26	24	21	21	21			72	76	45	45	93	96	66	84	198	200

Table No. 6.

Time.		Revolutions of induced-draft fans.				Steam pressures at fan engines.		Temperatures at fan inlets.				Temperatures in fan-engine rooms.				Vacuum in inches of water at fan inlets.			
		Port.		Starboard.				Port.		Starboard.		Port.		Starboard.		Port.		Starboard.	
P.	*S.*	Aft. No. 1.	For'd. No. 2.	Aft. No. 3	For'd. No. 4.	*P.*	*S.*	Aft No. 1.	For'd. No. 2.	Aft. No. 3	For'd. No 4.	Aft. No. 1.	For'd. No. 2	Aft. No. 3.	For'd. No. 4.	Aft. No. 1.	For'd. No. 2.	Aft. No. 3.	For'd. No. 4.
A.M.	A.M.					*Lbs.*	*Lbs.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
5.30	5.30	180	180	190	180	150	150	545	540	590	510	78	75	82	75	1.2	1	1.3	0.6
6 00	6.00	180	180	190	180	150	150	550	500	600	500	78	76	81	76	1 1	0.9	1 2	0.6
6 30	6.30	180	180	200	180	150	150	540	500	600	490	79	78	82	77	1.	1.2	1.2	1.
7.00	7.00	200	200	200	180	150	150	560	530	580	475	80	79	82	78	2.	1.	1.4	1.5
7.30	7.30	200	180	200	190	150	150	565	535	570	505	80	80	83	79	1.7	1.5	1.5	1.8
8.00	8.00	200	190	200	200	150	150	600	550	615	520	81	82	84	80	2.	1.6	2.	1.8
8 30	8.30	190	180	200	200	150	150	555	560	595	530	81	82	85	81	1.7	1.4	1.4	1.7
9.00	9.00	200	200	190	200	150	150	560	545	550	445	81	82	85	81	2.	2.2	1.6	2.



MAIN ENGINE INDICATOR CARD S. S. "DAKOTA."

TEST OF EVAPORATORS, U. S. S. *DIXIE*.

FROM A REPORT MADE BY LIEUTENANT NEWTON MANSFIELD, U. S. N., MEMBER.

DESCRIPTION OF PLANT.

There are three evaporators, rated capacity, 4,000 gallons per diem, single nest, straight horizontal-tube Navy type. All are fitted to take steam direct from the boilers, each having a trap to return this condensed steam to the feed tank in the engine room.

There are three straight-tube vertical distillers—two of Williamson Brothers' patent, of 3,750 gallons per diem each, and one vertical straight-tube Navy type, of 2,500 gallons.

One horizontal 9 by 8 by 12 Davidson pump furnishes circulating water.

One horizontal $5\frac{1}{2}$ by 5 by 5 Davidson pump feeds the evaporators.

One vertical, single-cylinder, Blake pump, $4\frac{1}{2}$ by $2\frac{3}{4}$ by 6, delivers the product of the distillers to two test tanks of 500 gallons each.

There are two filter tanks which are not used, except to catch the distilled water as it comes from the distillers.

The three evaporators are known as "A," "B" and "C." On December 24 to 27, 1903, an inch and one-half pipe was fitted to carry the product of "A" to the coils of both "B" and "C." A larger pipe, which was considered necessary, was not fitted owing to the limited time which the ship remained at the League Island Navy Yard. A separate connection was made from the traps of "B" and "C" to the distillers so that the product of "A" entering the coils of "B" and "C" could be trapped to the distillers, there cooled, pumped to the testing tanks and measured.

ARRANGEMENT OF THE TESTS.

The tests are divided into three stages, viz:

First Stage.—Running the plant double effect, steam being taken from the boilers only in the coil of "A," the product of all three evaporators being carefully measured in the test tanks.

"A" was blown down once every four hours, "B" and "C" once every twelve hours.

The pressure maintained in "A" was, coil, 55 pounds, shell, 35 pounds. That in "B" and "C," coils, 18 pounds, shells, 8 pounds. The speed of the circulating pump was 38 double strokes per minute.

Second Stage.—"A" was operated single effect, steam being taken into the coils of this one evaporator from the boiler, and returned to the boiler by the way of the trap and engine-room feed tank. The product was carefully measured. "A" was blown down once every four hours. The pressure maintained in "A" was, coils, 38, shell, 19. One distiller of 3,750 gallons capacity was found to be insufficient to condense the steam, so a second one was used, thus showing that the distillers are too small for the capacity of the plant when working single effect. The speed of the circulating pump was necessarily increased to 60 double strokes a minute.

Third Stage.—All evaporators and evaporator pumps being shut down, the coal consumed for all other auxiliaries in the ship for three days was carefully tallied.

CONDUCTING THE TESTS.

The following conditions were maintained as nearly as possible, viz:

Each stage was to continue for three days.

The auxiliaries in the whole ship were carefully noted, and an endeavor was made to have the time each one was in operation during each stage of the test equal that of each of the other two stages.

All the coal, excepting that for the galley and steam launch,

was carefully tallied for each stage. A number of buckets were weighed and an average obtained.

The first and second stages were carried on to completion, but the third stage was interrupted at the end of the fortieth hour by orders to get under way.

RESULTS.

Table I gives the number of hours that each auxiliary was in operation during each stage; also the total coal consumed by the boiler during each stage. Column IV is made up for 72 hours from column III, which is for 40 hours only. Column IV is then taken as the consumption of coal for all the auxiliaries during each of the three stages, as the auxiliaries in their time of operation varied but little.

Table I.

	Stage I.	Stage II.	Stage III.	
	72 hours. I.	72 hours. II.	40 hours. III.	72 hours. IV.
Evaporators "A," "B" and "C," double-effect, hours	72	0	0	0
Evaporator "A," single-effect, hours	0	72	0	0
Evaporator pumps, hours	72	72	0	0
Auxiliary condenser, hours	72	72	40	72
feed pump, hours	72	72	40	72
Flushing pump, hours	72	72	40	72
Ice machine (one), hours	72	72	40	72
One dynamo,* hours	73	73	43	77
Fresh-water pump, hours	20	21	9	16
Fire pump, hours	16	12	4	7
Machine-shop engine, hours	4	8	5	9
Deck winches, hours	2	0	0	0
Steering engine, hours	1	0	0	0
Total coal consumed, pounds	47,752	45,110.4	12,700	22,860
Water produced, gallons	21,000	10,000	0	0

* Two dynamos were in operation 1 hour.

Subtracting, then, column IV from column II, we have—

(1) Coal consumed by "A," single effect, in 72 hours, pounds.... 22,250.4
(2) Water produced by "A," single effect, in 72 hours, gallons.. 10,000
(3) Pounds of coal to produce one gallon of water, single effect.. 2.225

and subtracting column IV from column I, Table I, we have—

(4) Coal consumed by "A," "B" and "C," double effect, in 72 hours, pounds..... 24,892

(5) Water produced by "A," "B" and "C," double effect, in 72 hours, gallons..... 21,000

(6) Pounds of coal to produce one gallon of water, double effect 1.185

Comparing (3) and (6)—

Saving in coal to produce one gallon of water by running double effect, pounds..... 1.045

The expenditure of water for ship's use is in one month, gallons 98,500

make-up feed for one month, gals... 9,000

in one month, gallons..... 107,500

Saving in coal in one month by using double effect, pounds..... 112,337.5

tons..... $50\frac{337}{2240}$

year by using double effect, tons..... $601\frac{1804}{2240}$

At $4.50 per ton, saving in one year in cost of operation..... $2,708.12

CONCLUSION.

To further the fighting efficiency as well as the operating efficiency, all of our naval vessels should have their evaporating plants operated on the double-, or better still, the triple-effect systems.

THE TURBINE STEAMSHIP *VICTORIAN.*

REPORT MADE BY COMMANDER A. B. CANAGA, U. S. N., MEMBER.

In obedience to the Department's orders of April 1, 1905, I proceeded to Halifax, Nova Scotia, and made the passage to Liverpool, England, and return on the turbine steamer *Victorian* of the Allan Line, plying between Liverpool and Canadian ports, in order to observe the performance of the turbine machinery.

It is a matter of regret that my orders required me to make the return trip by the first turbine steamer sailing, which was the *Victorian*, as an inspection of the operation of the turbines of the sister steamer, the *Virginian*, would have been particularly interesting and valuable, since these turbines were constructed by the Parsons Marine Steam Turbine Company, while those for the *Victorian* were constructed from Parsons' plans by Workman, Clark & Co., of Belfast, the builders of this vessel.

The managers, agents and ship's officers were courteous and obliging, and I was allowed to examine the arrangement of all machinery and to inspect freely its operations, both while maneuvering and when in free route.

DIMENSIONS OF S. S. *VICTORIAN.*

Length, feet,	540
Beam, feet,	60
Draught, feet,	27
Tonnage, gross, tons,	11,200

The draught at Liverpool was 27 feet 6 inches, aft; was unable to obtain draught forward. At Quebec, after making the trip from Liverpool, the draught was 23 feet 6 inches forward and 26 feet 6 inches aft. The draught as given was taken

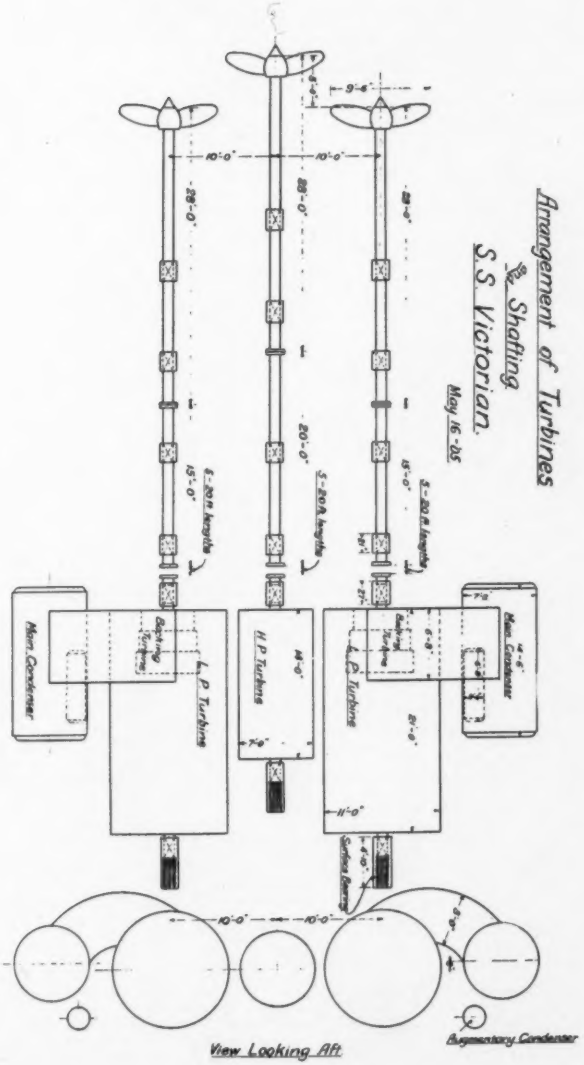

Arrangement of Turbines & Shafting
S.S. Victorian.
May 16-25
Main Condenser
H.P. Turbine
L.P. Turbine
Main Condenser
Auxiliary Condenser
View Looking Aft

Fig. 1.

in brackish water and after the vessel had completed the voyage from Liverpool, and it was, of course, greater than would have been shown with same displacement in open sea.

BOILERS.

There are eight cylindrical boilers of the "Scotch" type constructed for working pressure of 180 pounds per square inch.

Three double-end boilers:	
Diameter, feet	16
Length, feet	20
Three single-end boilers:	
Diameter, feet	17
Length, feet	12
Two single-end boilers:	
Diameter, feet and inches	14–2½
Length, feet and inches	11–6
Total grate surface of all boilers, square feet	797.5
heating surface of all boilers, square feet	31,478
H.S. ÷ G.S.	39.4

There are four furnaces in each single- and eight in each double-end boiler.

Length of grates, feet	5
Width, feet	3
Diameter of boiler tubes, inches	2½

Boiler tubes are fitted with retarders.

There is one elliptical smoke pipe for all boilers; outside casing, 16 feet by 19 feet 6 inches.

The fire rooms, two in number, are arranged athwartships. The furnaces of three single-end and the forward furnaces of the three double-end boilers are worked from the forward fire rooms, while the after furnaces of the double-end and the furnaces of the after two single-end boilers are worked from the after fire room.

The original design contemplated three single and three double-end boilers. This was changed during construction and two additional single-end boilers were installed in space originally allotted to pumps and other auxiliaries.

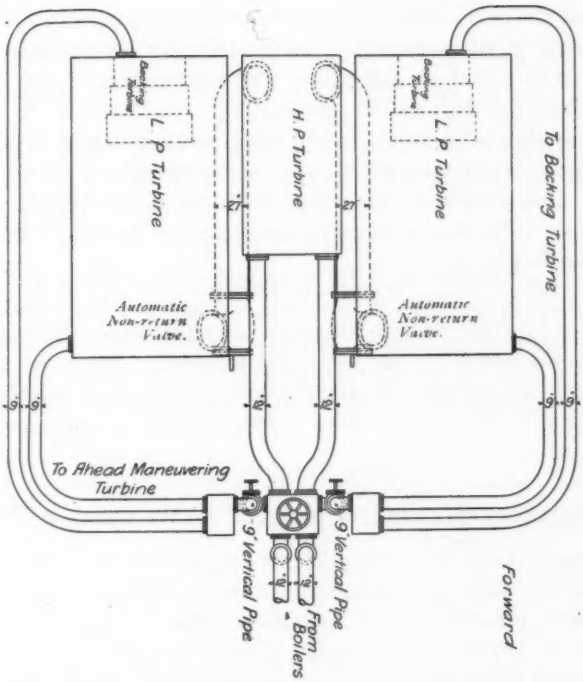


Fig. 2.

BLOWERS.

The boilers are fitted with hot-air draft of the Howden system. The air heaters are located in the uptakes. The blowers

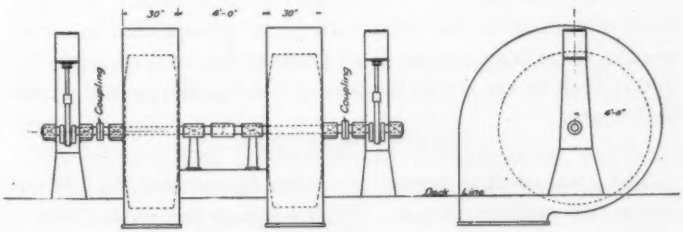


Fig. 3.

are on the orlop deck in roomy spaces, supplying the air at a pressure of 2¾ inches to 3 inches in the blower casing and ¾ inch to 1 inch in ash pits. The temperature of the air is raised to 190 degrees Fahrenheit.

The blowers are arranged in pairs, each pair fitted with two engines, each having sufficient power to operate the two blowers. One engine of each pair is disconnected and kept in reserve. The arrangement of coupling the blowers in pairs is shown in Fig. 3.

COAL BUNKERS.

The bunkers have a capacity of 2,400 tons. The main bunker is forward of the boiler compartment. There are wing bunkers abreast the two after boilers, and these connect with hanging bunkers at the sides of forward half of engine room.

MAIN FEED PUMPS.

There are two main feed pumps of the Weir pattern $\frac{14 \times 19}{30}$ inches, making 15 to 18 double strokes per minute. The long stroke of these pumps and the slow movement make them specially reliable in their operation. The feed water is taken from the hot wells and forced through the feed-water heater, where its temperature is raised to 180 degrees Fahrenheit by the exhaust steam from the pumps and other auxiliaries before being fed to the boilers. The condensed steam from the feed-water heater, which is located overhead, is drained back to the hot wells. The remaining uncondensed exhaust of the auxiliaries is passed on to the auxiliary condenser, where it is condensed and drained by gravity to the hot wells. The auxiliary condenser is not fitted with an air pump, and, in consequence, there is a pressure at all times of five to six pounds per square inch in the exhaust pipes of the auxiliaries and in the feed heater.

MAIN CONDENSERS.

The total cooling surface is 17,000 square feet, divided between two main condensers of 8,500 square feet each.

Diameter of tubes, ¾ inch; thickness, No. 16 L.S.G.

MAIN AIR PUMPS.

There is a duplex air pump of the Weir pattern for each condenser. Size, $\frac{11 \text{ inches} \times 31 \text{ inches.}}{21 \text{ inches.}}$ These air pumps, assisted by the Parsons intensifiers, were able to maintain a vacuum of 27 inches to $27\frac{1}{2}$ inches when making 38 double strokes per minute.

INTENSIFIER.

The intensifier, an invention of Mr. Parsons, is an apparatus similar in action to the steam ejector. Its function is to remove the air and vapor from the condenser and deliver them direct to the air-pump suction, thereby assisting in maintaining the high vacuum so necessary to the economic performance of the turbine.

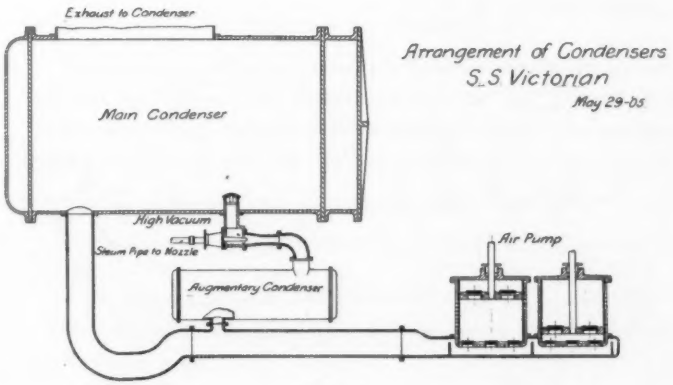


Fig. 4.

The steam jet carries the air and vapor through the intensifier to the augmentary condenser, where it is delivered to the air-pump suction near the air pump.

The location and arrangement of the intensifier and augmentary condenser with reference to the main condenser and air pump is shown on Fig. 4.

CIRCULATING PUMPS.

The circulating water for each condenser is supplied by a centrifugal circulating pump having 20-inch suction and discharge. The condensing water enters the condensers at the top, returns through the lower tubes and is discharged from the bottom of the water end.

Each centrifugal circulating pump receives its water through two 15-inch sea valves, the 15-inch pipes from these sea valves uniting into a main injection pipe 20 inches in diameter. There is also a 10-inch bilge-injection pipe fitted to each of these pumps. Each centrifugal pump is operated by two single engines, each of sufficient power to operate the pump at 170 revolutions per minute. The object in having the two independent engines fitted to each pump is to admit one engine being kept in reserve. The arrangement of pump and engines is shown on Fig. 5.

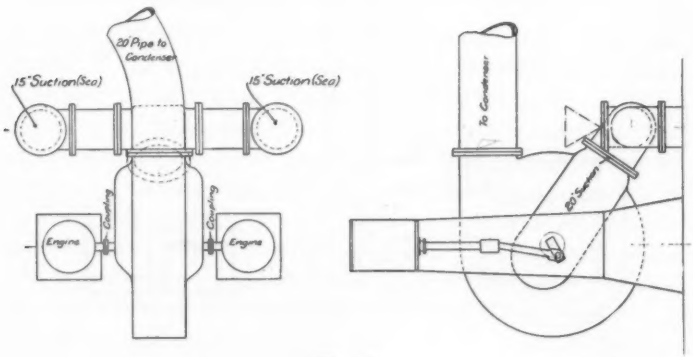


Fig. 5.

OIL PUMPS.

There are two oil pumps of about $\frac{4 \times 5}{6}$ inches supplying forced lubrication to the main bearings of the turbines One of these pumps is kept in reserve ready to be started at a moment's notice. As it is impossible to run the turbines without forced lubrication for their bearings, these pumps are

made of ample size and located conveniently at the working platform, forward end of the H.P. turbine. A pressure of 10 pounds is maintained continuously in the oiling circuit.

AUXILIARY PUMPS.

There are a number of auxiliary pumps for feeding the boilers, for supplying condensing water to the auxiliary condenser, for operating the ash ejectors, for pumping feed water from the reserve tanks, for pumping hot and cold water to the galleys and passengers' lavatories, for pumping out double bottoms, etc.

REFRIGERATING MACHINERY.

There is a carbon di-oxide refrigerating machine of about twelve tons capacity on a flat over the engine room used for refrigerating purposes alone.

DYNAMO MACHINERY.

There are two direct-connected dynamo sets of 60 kw. each generating current for lighting ship and for operating the dough-kneading machine, dish-washing machine, revolving spits and the Sirocco ventilating blowers.

DECK AUXILIARIES.

The anchor, winch and steering engines are all operated by steam.

PROPELLERS.

There are three propellers, all the same size, and having four blades each.

Diameter, feet and inches	9– 6
Pitch, feet and inches	8– 6

I was unable to learn the area of the propeller blades.

TURBINES.

The steamship *Victorian* is fitted with turbines built by Workman, Clark & Co., shipbuilders and engineers, of Belfast, under license from the Hon. C. A. Parsons and the Parsons Marine Steam Turbine Company.

The turbines for the sister ship *Virginian* were built from the same plans, but by the Parsons Marine Steam Turbine Company. There is a prevailing belief that the turbines of the *Virginian* are better, and more carefully built, and are already showing their superiority. A memorandum of the daily runs on the first trip from Liverpool to Halifax showed that the *Virginian* had made somewhat better speed than her sister, the *Victorian.*

There are three turbines, one high-pressure operating the central and two low-pressure operating the wing propellers. The central and starboard screws are right-hand; the port screw is left-hand.

The line shafting for each turbine is made up of six sections, each 20 feet long, except the after sections of the wing turbines, which are 15 feet in length. The propeller shafts are of the same length and interchangeable. The wing propellers are located 5 feet forward of the central propeller, as shown on Fig. 1. The shafts are parallel and spaced 10 feet center to center. The line and propeller shafting are forged solid and are rough-turned, 11½ inches in diameter, except at journals, where they are smoothed and polished.

The line shafting for each turbine is supported by fifteen bearings, 21 inches in length. Diameter of the journal in bearings same as diameter of the shafting. The line shaft bearings are fitted with oil rings, and are kept cool by water circulation through the bearings.

All main bearings of the turbines, both forward and aft, are 15 inches in diameter by 20 inches in length. These bearings are fitted with forced lubrication. The lubrication of these bearings is so important that it is necessary to have the system duplicated, maintaining at all times one oil pump in reserve.

The main and line shaft are all fitted with closed-circuit water circulation, one circuit taking water from the top of the forward water end of port condenser leads to all the line shaft bearings, the other leading from the top of the forward water end of the starboard condenser to the main bearings of the turbines. The two circuits unite at a small auxiliary pump

which forces the water from the bearings through the oil cooler and on to the deck for sanitary purposes.

The oil in the forced-lubrication system is passed through the cooling coils and thence to a settling tank, from where it is pumped again to the bearings. There is a small waste of oil in the forced-lubrication system, and this is made up from time to time by fresh oil. The temperature of the oil in the forced-lubrication system remained at a temperature of 70 to 72 degrees Fahrenheit.

MAIN STEAM PIPING, FIG. 2.

The steam from the boilers is led into the engine room through two 12-inch steam pipes uniting in the throttle valve

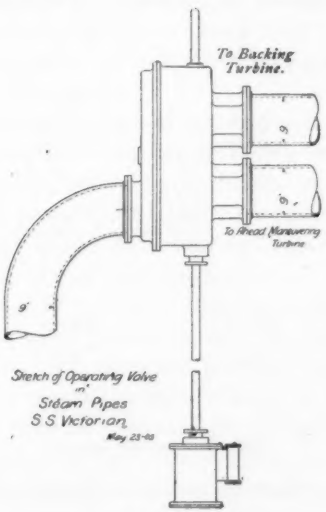


Fig. 6.

at the working platform. From the throttle valve the steam is led through two 12-inch pipes to the H.P. turbine. When in free route the steam is passed through the H.P. turbine where it separates, half going to the starboard and half to the port turbine through 27-inch receiver pipes, and from thence

through exhaust pipes 6 feet 8 inches × 5 feet to the main condensers. For maneuvering, the main throttle is closed and steam admitted to the maneuvering valves, one for each L.P. turbine. The operating or maneuvering valves on the *Victorian* are worked by a steam cylinder shown on Fig. 6. They are simply slide valves, which, when placed at the upper end of stroke, admit live steam to the forward end of the low-pressure turbine, when at the bottom end of stroke admit live steam to the backing turbine, and when in mid position shut the steam from both the ahead and backing turbines.

Fig. 7.—GAUGE BOARD.

In order to prevent the steam blowing back into the H.P. turbine when maneuvering, non-return valves are fitted in the receiver pipes between the H.P. and L.P. turbines, as shown on Fig. 4. These valves are automatic, opening or closing as the live steam is admitted to the H.P. or L.P. turbines.

At forward end of each turbine shaft is fitted a safety governor, which, in case of accident to propeller or shafting, operates to close the main throttle valve. It was noticed that

while handling the turbines these governors served another purpose, indicating whether the turbines were at rest or in motion. From the working platform these governors were the only visible moving parts of the turbines.

The counters register one revolution for ten revolutions of the turbines. The gear for operating the counters is located on the shafting just abaft the after main bearings.

OPERATION.

As a rule the turbines are easily and quickly handled, the change being made from the conditions of free route to conditions for maneuvering by simply closing the main throttle and opening the maneuvering stop valves. The action of the maneuvering valves is instantaneous, and the turbines respond immediately to the signals. It is noted that the minor mishaps and annoyances met with in a reciprocating engine were to be found with the turbines.

Heating of the main bearings of turbines is, however, a more serious matter than with the reciprocating engines, as the melting of the white metal or unusual wear in these bearings would cause a serious interference between the rotors and casing. Ample surface of main bearings and careful lubrication reduce the chances of such heating.

After being under way three or four hours from Liverpool, the after main bearing of the port L.P. turbine heated, making it necessary to stop this turbine and proceed at a reduced speed with the other two. Owing to the rolling of the ship, some grit that had settled in oil reservoir was carried to the bearing surface, causing the heating. The trouble was soon discovered, so that little damage was done beyond a delay of about twenty hours at Moville while overhauling and cleaning the heated bearing. It was noted that during the remainder of the trip this bearing gave no further trouble.

There was some annoyance due to priming of boilers and water being carried over to the turbines from time to time. This, however, is not the same menace to the turbines as to reciprocating engines, when water carried over into the cyl-

inder is liable to cause damage to the cylinder heads and pistons.

It is anticipated that this difficulty from priming, in a great measure, will disappear as the boiler plates and tubes lose the mill scale.

There was a pleasing absence of vibration, not only in the engine room, but throughout the ship, owing to the rotary motion and the perfect balance of the turbines. The propellers are also perfectly balanced, and, having a high speed of rotation, allow a corresponding reduction in their diameters. The small diameter admits of a much deeper immersion and consequent absence of racing. It was impossible to detect the slightest variation in the rotation of the turbines when the vessel was pitching in a heavy head sea. It is estimated that the tips of the blades at the highest points of their paths are still immersed 14 feet, which would require a degree of pitching rarely or never experienced before the propellers would be released sufficiently to allow of racing. This security from racing is a comfort to the passengers as well as to the engineers, as many of the troubles and mishaps to the propelling machinery come when the engines are racing and the vessel is straining and laboring in heavy seas.

Against this immunity from racing, due to the small diameter of screw with great immersion, must be set its lack of holding power. It was observed that the influence of head winds and seas reduced the vessel's speed considerably more than would have been the case with the large propellers used with reciprocating engines.

ENGINE-ROOM VENTILATION.

The radiation and leakage from the turbines and their connections makes the working platform and other working spaces in the engine room hot and uncomfortable, even though provision was made for the supply of fresh air by two 30-inch ventilators and for the escape of the hot air by a trunk 10 feet by 12 feet leading to the bridge deck. The after forced-draft blowers draw a part of their supply from the engine-room hatch

at a level of orlop deck. This arrangement, however, left the outboard and after parts of the engine room without ventilation. This, no doubt, will be remedied in future designs by ventilating blowers delivering fresh air into the dead-air spaces.

COMPARISON.

A comparison of the daily runs showed that the *Virginian* made somewhat better speed than the *Victorian.* It was not apparent whether the increased speed of the former vessel was due to greater coal consumption or to the more careful construction of the turbines, or entirely to the influence of the wind and sea.

A practical test on each of the vessels showed that the auxiliaries used 11 per cent. to 12 per cent. of the total boiler power. This result was obtained by using one boiler exclusively for running the auxiliaries.

The average speed taken from twelve representative daily runs was 15.3 knots, and to maintain this speed it is estimated from observation of firing that the total daily coal consumption was 172 tons. The exact coal consumption could not be obtained from the company's officials.

Deducting from this total daily coal consumption 12 per cent. for the auxiliaries, leaves 172—20.6=151.4 tons for the *Victorian's* propulsion alone.

There being no direct means of determining the I.H.P. of large marine turbines, it becomes necessary to arrive at their power by comparison with known results from similar vessels. On the trial of the S. S. *Friederich der Grosse*, a vessel similar to the *Victorian* in dimensions, model and speed, it was found that 7,200 I.H.P. gave a speed of 14.8 knots.

FRIEDERICH DER GROSSE.

Length, feet and inches	525-10
Beam, feet	60
Draught, mean, feet	27
Gross tonnage	10,526
Twin screws.	
Engines, quadruple-expansion, inches	25½ × 35⅛ × 52½ × 75½
Stroke, inches	55½
Coal consumption per 24 hours for propulsion, tons	115.5
per I.H.P. per hour for propulsion, pounds	1.54

Raising the speed of the *Freiderich der Grosse* to 15.3 knots would require

$$\frac{15.3^3}{14.8^3} \times 7{,}200 = 7{,}956 \text{ I.H.P.}$$

Taking the ratio of the gross tonnage of the two ships indicates that the *Victorian* would require

$$\left(\frac{11{,}200}{10{,}526}\right)^{\frac{2}{3}} \times 7{,}956 = 8{,}544 \text{ I.H.P. for a speed of 15.3 knots.}$$

With reciprocating engines (based on *Friederich der Grosse's* performances of 1.54 pounds per I.H.P. per hour) the *Victorian* would require per 24 hours for propulsion alone $\frac{8{,}544 \times 1.54 \times 24}{2{,}240} = 141$ tons, in order to get results equal to those obtained on the *Friederich der Grosse.* Attention is called to certain conditions which effect the economical results. The *Friederich der Grosse's* engines were quadruple-expansion and used steam of 213 pounds pressure, while the *Victorian* used steam pressure of only 160 pounds. The vacuum of the port condenser was not good during several days owing to air leak, perhaps through the steam packing of port L.P. turbine. Besides, as mentioned previously, the boilers primed at times, which no doubt interfered with the economic performance of the turbines. The disturbing influence of the above-mentioned conditions no doubt will be overcome entirely or materially reduced, bringing the economic operation up to good reciprocating practice.

As results appear at present the *Victorian* is using 151.4—141=10.4 tons more coal per twenty-four hours than would have been used with good quadruple-expansion engines, using steam 210 to 220 pounds per square inch.

It is anticipated that this excess of coal consumption per day will be reduced even for the *Victorian's* turbines, and will disappear entirely with future designs, when it is more fully understood just how much the propellers ought to be reduced and just how much the speed of the rotation of the turbines should be increased. What has already been done at this early day in the improvement of the turbine presages its speedy development

for marine purposes. On land, in power plants with turbine motors, results have been obtained showing its economic superiority to the reciprocating engines.

OILING.

The number of bearings and working parts for turbine machinery is reduced to a minimum, and in consequence the oiling arrangement is simplified and the expense for oil reduced below that necessary for reciprocating engines. For the main bearings of the turbine there is but little waste, as the closed lubricating circuit allows the oil to be used over and over.

There is, however, no reduction in the oil expenses for the auxiliary machinery, as it is of the usual type installed with reciprocating engines.

PERSONNEL.

It has been suggested that with the less complicated machinery of the turbines that a considerable reduction would be possible in the engineer's force, but as the force necessary for the auxiliary machinery and for the fire rooms is about 85 per cent. of the total force, and remains approximately the same whether the main engines are turbine or reciprocating, very little reduction in engineer's force is possible.

An inspection of the list of men in the engineer's force of the *Victorian* shows that it cannot be reduced judiciously beyond its present numbers.

ENGINEER'S FORCE ON *VICTORIAN.*

1 Chief engineer.
7 Assistant engineers.
6 Engine-room oilers.
3 Leading firemen.
30 Firemen.
21 Coal passers.
1 Storekeeper.
1 Assistant storekeeper.
1 Electrician.
3 Dynamo oilers.
1 Oiler for refrigerating machinery.
1 Machinist for deck auxiliaries.

SYNOPSIS OF STEAM LOG.

On Table I is tabulated the observations of pressures and revolutions for the turbines and some of the more important auxiliaries.

Table I.—SYNOPSIS OF STEAM LOG—S. S. *VICTORIAN.*
Data taken on trip Halifax—Liverpool—Montreal.

Boilers.					Turbines.				Condensers.						Pumps.	
	Air pressure, inches water.				Gauge pressures at inlet.				Vacuum in inches.				Temp.			
									Main.		Augmentary.					
Pressure per sq. in. (gauge).	Blowers casing.	Ash pit.	Feed heat pressure per sq. in.	Blowers, revolutions per minute.	H.P.	Stb'd L.P.	Port L.P.	Revolutions per minute.	Stb'd.	Port.	Stb'd.	Port.	Inj.	Disch.	Circ. pump, R. P. M.	Air pump, doub. str.
145	2¾	¾	5	...	100	12	12	210	27	27	27	27	...	...	...	40
155	2¾	...	6	...	100	14	14	220	27½	27½	27½	27½	...	...	...	...
170	3	1	6	275	133	18	18	232	25	25	...	...	48	72	160	40
170	...	...	6	...	140	20	20	236	24	24	24	24	...	...	...	...
165	...	...	6	280	150	21	21	238	27	27	27	27	...	...	...	38
165	...	...	5	...	140	22	22	210	27	23	27	23	...	...	...	...
150	...	...	6	280	120	15	15	*	27½	24	27½	24	...	...	...	26
150	...	...	6	...	120	15	15	†	26	19	25	19	...	...	...	...

* H.P. = 220; starboard L.P. = 220. † Port L.P. = 210; 200.

Table II.—SYNOPSIS OF LOG, S. S. *VICTORIAN.*

	Date, 1905.	Sailed from—	Arrived at—	Latitude.	Longitude.	Distance.	Speed.*
Halifax to Liverpool.	April 11.	Halifax, 6 A. M.	.....	*North.*	*West.*		
	11.	.....	.....	43·50	61·50	89	14.8
	12.	.....	.....	42·28	54·00	357	15.2
	13.	.....	.....	42·23	46·00	370	15.8
	14.	.....	.....	45·53	39·00	365	15.6
	15.	.....	.....	49·02	32·04	342	14.6
	16.	.....	.....	51·50	23·59	353	15.1
	17.	.....	.....	54·24	15.10	356	15.2
	18.	Moville, 1·30 P. M.	Moville, 9·30 A. M.	...	...	...	...
	19.	.....	Liverpool, 2·30 A.M.	...	...	195	15
Liverpool to Montreal.	April 27.	Liverpool, 6 P. M.	.....	...	...	...	...
	28.	.....	Moville, 1·30 P. M.	...	...	195	10
	28.	Moville, 8·30 A. M.	.....	...	...	53	15.2
	30.	.....	.....	54·36	19·30	393	15.9
	May 1.	.....	.....	53·11	29·45	372	15.1
	2.	.....	.....	50·32	39·20	388	15.7
	3.	.....	.....	47·37	46·04	317	13
	4.	.....	.....	45·51	53·15	341	13.9
	5.	.....	.....	47·32	59·05	280	11.5
	6.	.....	.....	48·40	62·26	152	6.2
	7.	.....	.....	47·39	70·03	344	14.1
	7.	.....	Quebec, 7 P. M.	...	...	...	...
	8.	Quebec, 5 A. M.	Montreal.	...	...	...	...

* Average speed in knots per hour.

It will be noted in the last three readings that the vacuum in the port main condenser was considerably lower than for the starboard condenser. This falling off is attributed to an air leak, as the air and circulating pump of this condenser were run at the same speed as those on starboard side.

DAILY RUNS.

Table II gives the daily runs for both the east- and west-bound voyages. The last column gives the average speed in knots per hour, corrected for the difference of longitude.

During May 3d and 4th a moderate gale from the west and heavy head seas caused a decided falling off in speed. The reduced runs for May 5th and 6th are due to delays caused by ice in Gulf of St. Lawrence.

CONCLUSIONS.

There exists a difference of opinion between those interested as to the final status of the steam turbine. The energy and intelligence now bestowed on the turbine motors will decide the position it is to take with its time-honored competitor, the reciprocating engine.

In new power installations on land the turbine has gained a footing that warrants the belief that it has come to stay, the character of work in large power plants admitting of arrangements that will insure the units operating at all times on a full and constant load. Under these conditions the turbine has proved its superiority over the reciprocating engine. With this advantage in its favor it is, however, not believed that it will displace expensive reciprocating machinery already in place and doing its work to the satisfaction of owners and patrons.

The change from reciprocating engines to steam turbines for marine propulsion is not so easily made, owing to the difficulty met at high speeds of rotation in overcoming economically the inertia of water acted on by the propeller, and, further, the falling off in economy when the speed of rotation of turbines is reduced to suit the advantageous but slower rotary speed of the

propeller. An equitable compromise between the speed of rotation of the turbine and propeller for maximum power and speed is upset and economy sacrificed when a reduced speed and power is attempted. As a solution, the Parsons Steam Turbine Company fit small cruising turbines in naval vessels for use when cruising speed with consequent reduced power is desired.

The cruising turbines require additional engine-room space and add somewhat to weight of propelling machinery. In the present development of the marine turbine this increase in necessary space and weight is not considered a loss, as the combination of the cruising with the main turbines enables the vessels so fitted to keep the sea longer, while still retaining in reserve the advantage of speed.

The length fore and aft of the *Victorian's* engine room is 39 feet 6 inches, and the three turbines and two main condensers being placed abreast, as shown on Fig. 1, occupy the space from side to side of the vessel. There is no gain in floor space for turbine over that required for reciprocating machinery of equal power, but in head room there is a decided advantage in favor of the former, especially in naval vessels.

At the *Victorian's* representative speed of 15.3 knots per hour obtained with 229 revolutions per minute, the slip of propeller was 20.4 per cent.—a very good result so far as slip is concerned, and indicates that the search must be made in other directions for elements that are to make the steam turbine more nearly what is needed for marine purposes. It has already been mentioned that there was considerable priming, and although this condition is not a menace to the turbine, it acts as a great mechanical handicap. The resistance offered to the passage of water among the vanes instead of steam is considerable and must react equally to resist the rotation of the turbine. From experiments made to determine the action of superheated steam, it was found that the efficiency of the turbine was increased 10 per cent. by using steam superheated 100 degrees Fahrenheit. These results indicate an item of economy that should be taken into account in adapting the

steam turbine for marine purposes. It is not believed, however, that the use of superheated steam in marine turbines will give as good results as those just mentioned, which were obtained from comparatively small units. The large marine turbines will require additional clearances to allow for the expansion resulting from high temperatures of superheated steam.

The minimum clearances, the proportions for nozzles and openings between vanes, the best speed of rotation for marine purposes, etc., can be best obtained by numerous and carefully-conducted experiments made with turbines installed in vessels.

In Great Britain there are at present twenty-four vessels of various classes, either built or building, fitted with marine turbines, indicating a confidence in this type of marine motor. It is thought that this extensive introduction is due to a more substantial cause than the fascination of novelty. Possibilities have been discerned that outweigh the shortcomings shown by the poor performance of some marine turbines.

Important and interesting results have been gotten from trials of H. M. S. *Amethyst* and *Topaze*, sister ships, one with turbines and the other with reciprocating engines, showing that at a speed of 10 knots the turbines used about 19 per cent. more steam than the reciprocating engines. At 14 knots the steam consumption was the same for each type. At 18 knots the turbines used 20 per cent. less, and at 20 knots about 30 per cent. less steam than the reciprocating engines. These results mark important and flattering progress for the marine turbine, and strongly suggest that its use should be more general in vessels of the U. S. Navy.

It is therefore strongly recommended that hereafter turbines be installed in torpedo boats, destroyers, scout cruisers, and in gunboats. Their use in such vessels and the experiences gained therefrom will, no doubt, in time demonstrate the wisdom of fitting them in battleships and armored cruisers.

NOTES.

STEAM TRIALS OF H. M. S. *CARNARVON.*

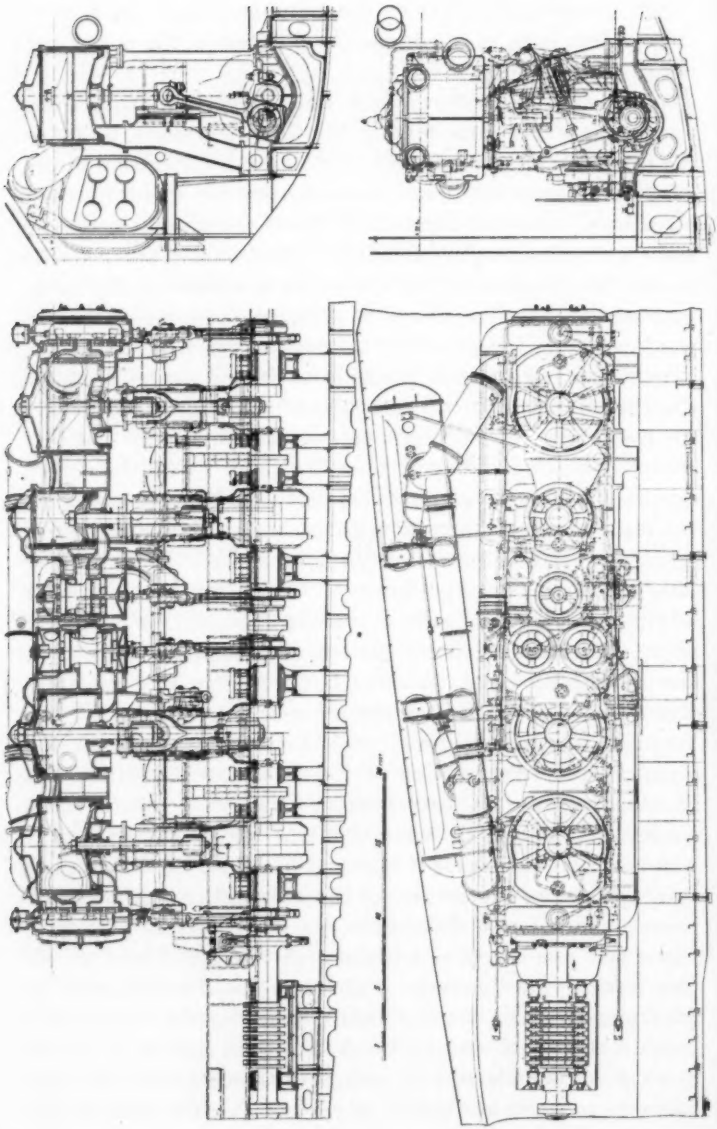
In the following description of the *Carnarvon*, taken from "Engineering," of London, March 17, there will be noted a number of points of more than ordinary interest.

The most striking departures from the usual naval practice will be found in the system of forced lubrication for main engine bearings and the arrangements for the recovery of oil from crank pits, the omission of auxiliary condensers and the conditions under which the trial was run, the latter being such as would exist when in ordinary service.—EDITOR.

The armored cruiser *Carnarvon*, the first of the *Devonshire* class to be completed, has passed through her steam trials, and the results have proved thoroughly satisfactory, the mean speed attained on the eight-hours' full-power trial being 23.3 knots, while only 22.25 knots was anticipated in the design. This result is the more remarkable as it closely approximates to the average performance of the earlier cruisers of the County class, which are by no means so well armored, and have a much less powerful armament. The County cruisers were laid down at a time when there was a desire, while increasing the speed, to decrease the displacement and cost; consequently the tonnage was limited to 9,800 tons, and a speed of 23 knots was aimed at. In order to meet these conditions it was decided to have only 4½-inch armor on the broadside amidships, reduced to 3 inches forward, and ultimately to 2 inches at the ram; the conning tower, however, was of 10-inch armor. The armament consisted of fourteen 6-inch guns. Experience has shown that the limitations imposed were not justified. Even at the time the cruisers were built experts were satisfied that 4½-inch armor was quite inadequate to resist penetration by 6-inch and 7-inch modern high-ballistic guns, and that the building of a ship costing from £750,000 to £800,000, armed only with

6-inch guns—irrespective of the number of such weapons—did not anticipate to any degree the progress in the power and range of enemy's guns.

When the *Devonshires* were ordered, early in 1902, they were to be of the same type as the County cruisers, so far as the thickness of armor and the number and disposition of the guns were concerned; but, following upon the appointment of Mr. Philip Watts as Director of Naval Construction, the designs were considerably modified. The first step taken was to increase the thickness of the armor, the broadside plating being increased to 6 inches instead of 4¼ inches, tapering at the forward end to 4½ inches and at the ram to 2 inches. There was a corresponding increase in the thickness of the bulkhead at the after end of the main belt, which is now 4½ inches, while the conning tower has been made of 14-inch armor. The belt extends from well abaft the engine room to the bow; the depth amidships is practically 11 feet; but forward, owing to the sheer of the main deck and the droop of the protective deck towards the ram, this depth is increased to about 15 feet. This increased protection involved deeper draught; and later a further change was made, to considerably increase the power of the armament, as shown in the table of comparative particulars on another page. The early County cruisers had fourteen 6-inch guns; the *Devonshires* were designed to have two 7.5-inch guns and ten 6-inch guns, the former being bow and stern chasers. But in view of the strong opinion which had developed against the once popular 6-inch gun, because of its limitations in energy and range, it was decided to increase the number of 7.5-inch guns to four and to reduce the 6-inch guns to six. Thus, in the cruisers of the *Devonshire* class there are three 7.5-inch bow-chasing guns, one in a barbette on the forecastle and two others in barbettes on the upper deck at the after end of the forecastle. The bow fire thus becomes approximately fifteen shots of 200 pounds weight, each with a muzzle energy of about 11,600 foot tons, against forty-two shots of 100 pounds weight, each with an energy of from 5,000 foot tons to 5,500 foot tons. In view of the increased energy



ONE MAIN ENGINE H. M. S. "CARNARVON."

per shot, no two opinions can be entertained as to the superiority of the bow fire of the *Devonshire* class. As regards the stern fire, there is mounted on the upper deck one 7.5-inch gun in the barbette, while on each side there are double-story casements for 6-inch guns, the lower gun in each pair being on the main-deck level. Amidships on the main deck there is, on each broadside, one 6-inch gun. It seems, however, doubtful whether the 6-inch guns on the main deck can be fought in any seaway, because, apart from the rolling of the ship, there are always waves, so that the projectile may bury itself instead of ricocheting. It would appear, therefore, as if the four 6-inch guns placed on the main deck in this *Devonshire* class should have been dispensed with and additional 7.5-inch guns mounted on the broadside. The smaller guns in the ship include twenty 3-pounder quick-firing guns and two boat and field quick-firing guns of the 12-pounder 8-hundredweight class, in addition to two Maxim guns.

Table I.—COMPARATIVE PARTICULARS OF COUNTY AND *DEVONSHIRE* CLASSES OF CRUISERS.

	County Class.	*Devonshire Class.*
Length between perpendiculars	440 ft.	450 ft.
Breadth (molded).....	66 ft.	68 ft. 6 in.
Depth (molded).....	38 ft. 6 in.	38 ft. 6 in.
Draught (mean).....	24 ft. 6 in.	25 ft.
Displacement (normal)	9,800 tons	10,850 tons
Designed speed.....	23 knots	22¼ knots
Indicated horsepower...	22,000	21,000
Coals (normal).....	800 tons	800 tons
(bunkers full)....	1,750 tons	1,750 tons
Number of boiler rooms and funnels	3	4
Main Armament:	Fourteen 6-in. quick-firing	Four 7.5-in. and six 6-in. quick-firing
On forecastle deck.....	Two 6-in. guns, twin-mountings in barbette	One 7.5-in. gun in barbette
Upper deck at aft end of forecastle	Two 6-in. guns, one on each broadside, in casemates	Two 7-5-in. guns, one on each broadside, in barbettes
Upper deck aft under shelter	Two 6-in guns, one on each broadside, in casemates	Two 6-in. guns, one on each broadside, in casemates

	County Class.	*Devonshire Class.*
Upper deck aft of shelter	Two 6-in. guns, twin-mountings in barbette	One 7.5-in. gun in barbette
Main deck forward.....	Two 6-in. guns, one on each broadside, in casemates immediately under upper-deck guns	None
Main deck amidships...	Two 6-in. guns, one on each broadside, in casemates	Two 6-in guns, one on each broadside, in casemates
Main deck aft.....	Two 6-in. guns, one on each broadside, in casemates immediately under upper-deck guns	Two 6-in. guns on each broadside, in casemates immediately under upper-deck guns
Smaller guns:		
12-pounder 12-cwt. quick-firing	8	None
12-pounder 8-cwt. boat and field quick-firing	2	2
3-pounder quick-firing	3	20
0.303 Maxim automatic	2	2

The alterations made in the various ships have considerably delayed them. Messrs. William Beardmore and Co. are the first to complete one of the vessels of her class, an honor which also fell to them in connection with the completion of the *Berwick* of the County class. The next vessel to go on trial will be the *Antrim*, built and engined by Messrs. John Brown & Co., of Clydebank, to be followed by the *Devonshire*, built at Chatam Dockyard; the *Hampshire*, constructed by Sir W. G. Armstrong, Whitworth & Co., Newcastle-on-Tyne; the *Roxburgh*, by the London and Glasgow Company; and the *Argyll*, by Scott's Shipbuilding and Engineering Company, of Greenock.

In respect to boiler installation, there was also considerable range, as the plans for these ships were submitted to the Boiler Committee, and it was decided to adopt various systems of boilers. In all cases part of the installation consists of cylindrical boilers, as first recommended by the Boiler Committee; but experience has since shown that this is not a de-

sirable procedure. Not only does it involve complications, but it has been proved that the efficiency and economy of the cylindrical boiler are not equal to the results achieved by various types of water-tube boilers, working under exactly corresponding conditions in the same ship. The *Carnarvon* has Niclausse boilers, and cylindrical boilers with the closed stokehold system of forced draft; the *Devonshire* has Niclausse and cylindrical boilers on the Howden system; the *Roxburgh* has the Dürr boiler, with closed-stokehold forced-draft for the cylindrical boilers; the *Antrim* has Yarrow and cylindrical boilers, both forced on the Howden system; while the same boilers in the *Hampshire* are on the closed-stokehold system. The *Argyll* has closed stokeholds for the cylindrical boilers, but natural draft is adopted for the Babcock & Wilcox boilers. It remains to be seen whether full advantage will be taken of these variations for comparative experimental tests. Time, a staff, and money must be found, if the confusion involved in the variety is to be justified.

Confining ourselves now to the *Carnarvon*, the machinery for which has been constructed by Messrs. Humphrys, Tennant & Co., of Deptford, London. It will be noted that there are six single-ended tank boilers in the aft stokehold, while in each of Nos. 2 and 3 stokeholds there are eight boilers of the Niclausse type; in the forward stokehold, where the lines of the ship reduce the width of the hold, there are only six. In each stokehold there are fitted two of Weir's feed pumps and a See ash ejector. There are thus twenty-two Niclausse water-tube and six cylindrical boilers. Fourteen of the Niclausse boilers have 15 sections, six have 14 sections, and two 12 sections, each section consisting of a header with twenty-two steel tubes, 3.3 inches in external diameter; the headers are connected to the steam collectors by coned joints. The total heating surface in the twenty-two Niclausse boilers is 43,566 square feet, and the grate surface 1,224 square feet, the length of firebars being 6 feet 6½ inches. The cylindrical boilers are 13 feet in diameter and 9 feet 1 inch long, each having three corrugated furnaces 3 feet in inside diameter, and

364 steel tubes 2½ inches in external diameter, and 6 feet 0½ inch long between the tube plates; the total heating surface in the six boilers is 10,158 square feet, and the grate surface 324 square feet, the length of the firebars being 5 feet 9½ inches.

The propelling machinery consists of two sets of four-cylinder triple-expansion engines arranged in separate water tight compartments, with a longitudinal bulkhead. The engines were designed to develop collectively 21,000 indicated horse-power at 138 revolutions per minute, with a pressure in the boilers of 210 pounds per square inch. The cylinder covers, pistons and bottom frames are of cast steel. The cylinders of each set of engines are supported at the front by six forged-steel turned columns, and at the back by four cast-iron rectangular columns, on which are bolted the guides for the piston-rod shoe plates. The diameters of the cylinders are high-pressure, 41½ inches; intermediate, 65½ inches; and two low-pressure, 73½ inches; all having a stroke of 42 inches. All the cylinders are fitted with liners, and are steam jacketed. The high-pressure and intermediate-pressure liners are made of solid forged steel, and those for the low-pressure cylinders of cast iron. The distribution valve on the high-pressure cylinder is of the piston type; the intermediate cylinder has two piston valves, operated by seperate spindles connected to a crosshead. Slide valves are provided for the two low-pressure cylinders. Starting valves are fitted to the intermediate and low-pressure valve casings. The reversing gear is of the well-known Humphrys type, reversing being effected by means of a screw; there is also an automatic cut-off to the main engine.

The shafting is hollow throughout; the crank shaft is 18 inches in diameter, with a 9-inch hole; the crank pins are all 20 inches in diameter, those for the high-pressure and intermediate-pressure being 26 inches long, and for the low-pressure 17 inches long. The angles of the cranks are arranged on the Yarrow, Schlick and Tweedy system, to balance the weight of the moving parts. Forced lubrication has been applied experimentally to some of the bearings in the *Carnar-*

von, the intention of the Admiralty being to develop a satisfactory system in connection with the whole of the crank-shaft bearings, the main bearing, the crank heads and eccentrics. Messrs. Humphrys, Tennant & Co. have carried out extensive experiments on a large scale at their works, and they have fitted one of the main bearings and one of the crank heads of the *Carnarvon* with a system of forced lubrication, which, having proved very satisfactory, is now to be applied to all the bearings in the battleship *Britannia*, the engines of which are now being made by the same firm. The oil is pumped into the main bearing, in which it is confined by a species of gland on each end of the bearing; thence it is conveyed by means of holes to the center of the crank shaft, and in the usual manner to the crank-pin, and finally into the crank brasses. The oil is recovered from the crank pit, passed through filters, and again pumped through the main bearing in the same cycle. To reduce to a minimum the water required, special glands are fitted to the piston rod, so that any water passing the main gland can pass away to the bilge. In orher vessels of the *Britannia* class a different system is to be experimented with, in order to obtain experience and to evolve finally the most effective method. In connection with this, Messrs. John Brown & Co., who are building the machinery for the *Africa*, are also carrying out a series of important experiments. The Admiralty are indebted to such firms for devoting their experience and resources for the advancement of engineering in the service.

It will be noticed that the system of lubrication of the thrust block in the *Carnarvon* differs from that which we have hitherto seen in connection with naval machinery. The lubrication is in this case entirely effected by means of grooves cut on the collars of the thrust shaft, which in rotation dip into the oil contained in the well formed in lower part of the block. The oil is retained in this by means of small casings fitted between each separate collar. The temperature in the block itself is, therefore, a fair guide to satisfactory working. The system worked well during the trial of the *Carnarvon*, at a tempera-

ture which, judged by immersion of the finger point, seemed much greater than that possible under ordinary water cooling. The rings are solid; but we understand that with the next application of the same system water-cooled collars will be adopted, as experiments at the works of Messrs. Humphrys, Tennant & Co. have shown that a remarkable lowering of the temperature of the oil in the thrust block is effected when the heat generated is conveyed away by means of water passing through the collars.

There are two condensers for each engine. The one centrifugal pump for both condensers is placed on the upper platform, while on the lower platform there is located a filter tank. The condensers have each 6,575 square feet of cooling surface, and either may be shut off for overhaul, as the other is sufficient. Independent twin air pumps of the Weir type are placed forward of the condenser plant. They draw from the condenser, and discharge through grease filters into the feed tank. There is no auxiliary condenser in the ship, the exhaust from the auxiliary machinery being passed into the main condensers, or into the closed exhaust system, or into the receiver of the low-pressure cylinder of the main engine, or into the evaporator. There is one distiller, located at the after end of each engine room. This distiller is capable of taking the total output of both evaporators for making up the boiler feed. In many previous ships the boiler make-up was provided by one evaporator discharging into the main condenser; but in this case the evaporating and distilling system is a distinct unit of itself. The advantage of this is that the distiller, taking the whole of the output of both evaporators, gives feed water at a much higher temperature than is the case when it is working in conjunction with one evaporator for the production of drinking water. The rate of output of fresh water is adjusted in each case, to insure a high or low temperature of fresh water at the outlet. The engine rooms are identical in arrangement, and have donkey and bilge pumps.

The trials of the *Carnarvon* were carried out under the new service conditions, which require that the staff employed and

the arrangements on board shall agree exactly with those obtaining when the ship is in war service. Thus all bulkhead doors were shut, the engine room was closed down, the staff was restricted to the service complement, the amount of oil used was limited, and no water was permitted on the bearings. Clearances were also prescribed. In view of the severity of these conditions when applied to new machinery, the proportion of power required to be developed on the second thirty-hours' trial was reduced from 80 per cent., as in previous cruisers, to 70 per cent. of the full power. This is the power which can be maintained as long as the coal may last and can be brought to the stokehold plates. No difficulty whatever was experienced in obtaining the results, and as regards the temperature of the closed-down engine room, the highest reading—and that for a short period only—was 90 degrees Fahrenheit, while in the ammunition passages and other parts of the interior it was 75 degrees Fahrenheit. The outside temperature was, if anything, higher than is usual at this period of the year. The ease with which ship after ship is passing through her trials under the new conditions clearly shows that no trouble need be anticipated, even in running for thirty hours at 80 per cent. power, and in the future the sea-going engineer will not be able to point to any favorable circumstance during trials in extenuation of any inability to maintain the legend speed in service, an excuse sometimes, although not often, made.

On the first trial, which was of thirty hours' duration, the vessel steamed from the Clyde to Portsmouth, and experienced very severe weather, the wind blowing with a force of 10 for the greater part of the time. The steaming results are set out in Table II, from which it will be seen that the mean power was 4,756 horsepower, while the coal consumption worked out to 2.11 pounds per indicated horsepower, and the loss of water to 2.14 tons per 1,000 indicated horsepower per twenty-four hours. Before returning to the Clyde the vessel proceeded to the English Channel to carry out her gun trials, with a view of testing the mountings and adjacent ship structure. The

Table II.—STEAM TRIALS OF H. M. S. *CARNARVON.*

	30 One-fifth power coal consumption.		30 70 per cent. power coal consumption.		30 Full power.	
	Starboard.	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*
Mean steam in boilers, pounds	184		205		202	
at engines (H.P. receiver), pounds	89	97	171	170	173	173
air-pressure in stokeholds,* inch	...	...	0.4	0.4	0.7	
cut-off in H.P. cylinder, per cent	...	...	59.8	59.8	77	77
vacuum, inches	26.1	26.9	26.8	27.3	26	25.5
revolutions	84.2	84.4	129.2	128.3	141.7	142.5
Mean pressure in cylinders, high, pounds	36.8	39.8	73.8	73.9	89.5	90.9
intermediate, pounds	10.6	11.72	24.4	25	29.7	30.1
low, forward, pounds	5.44	5.5	12.35	11.84	15.45	16.66
aft, pounds	4.64	5	10.9	10.2	15.12	15.79
I.H.P., high	889	963	2,692	2,722	3,640	3,727
intermediate	638	707	2,250	2,295	3,008	3,064
low, forward	411	417	1,436	1,367	1,971	2,138
aft	351	380	1,264	1,186	1,929	2,012
Total I.H.P.	2,289	2,467	7,642	7,570	10,548	10,941
Gross total I.H.P.	4,756		15,212		21,489	
Coal consumption per I.H.P., pounds	2.11		1.78		2.29	
Speed of ship, knots	14.3		21.43		23.3	
Total loss of water, tons	12.76		44.02		25.5	
per 1,000 I.H.P. per 24 hours, tons	2.14		2.31		3.5	
Water made by evaporators, tons	12.74		41.07		...	

*Only applicable to stokehold with cylindrical boilers.

gun mountings were fitted by Sir W. G. Armstrong, Whitworth & Co., and gave every satisfaction, while the ship withstood the stresses splendidly.

The second trial of thirty hours' duration was carried out when the vessel was returning to the Clyde. This trial took place on Tuesday and Wednesday of last week, and again very severe weather conditions were met with, the wind being of force 8 to 10. The results are given in Table II. There was an air pressure of 0.4 inch in the stokehold with cylindrical boilers. The power developed was 15,212 indicated horsepower, the coal consumption being 1.78 pounds per horsepower hour, and loss of water 2.31 tons per 1,000 indicated horsepower per twenty-four hours. The contract required that during this run the power should be 14,700, which, it will be noted, was exceeded by 500 horsepower. During this trial, on the 8th instant, two runs were made on the measured mile at Skelmorlie on the Clyde. On the first run the engines made 132.8 revolutions, and developed 15,304 indicated horsepower, which gave a speed of 22.195 knots. On the second run the mean revolutions were 129.6, the power developed being 15,398, while the speed was 20.666 knots. The mean results were: Revolutions, 131.2; power, 15,351 indicated horsepower; speed, 21.43 knots. The displacement when the vessel was running the mile was 10,500 tons. The later cruisers of the County class made on this trial a speed of about 22 knots, with about 16,200 indicated horsepower, so that the *Carnarvon* has done exceedingly well, because not only is the power and aggregate coal consumption less, but the displacement was 1,700 tons greater. The increased armor and armament has thus been bought for a small forfeiture in speed—about half-a-mile per hour with the same power as in the County class.

The full-power trial took place on Friday, March 10th, when again the weather was unpropitious, a wind force of 4 to 6 blowing, with frequent squalls, of long duration, of force 10. On this trial the vessel started a little in excess of her designed displacement, and when four hours had elapsed she was put on the measured mile at Skelmorlie. It was then slack tide, so

that the only interference was due to the wind. It will be noted from Table III that the first and third runs occupied exactly the same time, which was also the case with the second and fourth runs, but the power varied. The fact that the speed is the same, notwithstanding the difference in power, is, of course, due to the difference in wind resistance. The mean speed was 23.3 knots, the engines having made 142.3 revolutions, and the indicated was 21,322 horsepower. The highest speed got with any of the vessels of the County class was 24 knots, with 22,881 indicated horsepower; and here again the performance of the *Carnarvon* must be regarded as satisfactory, for the loss in speed is only 0.7 mile per hour, notwithstanding that the power is 1,500 indicated horsepower less and that the displacement is 1,000 tons more. A high propulsive efficiency seems to have been attained, which is due partly to increased length and to the propellers. These are of Stone's manganese-bronze, 15 feet 9 inches in diameter, each having three blades, set at a pitch of 19 feet 6 inches. The total blade surface in each propeller is 80 square feet.

Table III.—FOUR RUNS ON MEASURED MILE AT FULL POWER.

Number of run.	Time.	Revolutions per minute.		Indicated horsepower.			Speed, knots.
		Starboard.	Port.	Starboard.	Port.	Total.	
	m. *s.*						
1	2 35.2	143.8	144.6	10,770	11,046	21,816	23.196
2	2 33.8	142.4	143.5	10,408	10,959	21,367	23.407
3	2 35.2	141.9	142.6	10,305	10,798	21,103	23.196
4	2 33.8	141.6	142.8	10,333	10,669	21,002	23.407
Mean of means	...	142.3	143.2	10,454	10,868	21,322	23.3

The water-tube boilers, which, as already indicated, are of the Niclausse type, as fitted and proved satisfactory on board the *Berwick* and *Suffolk*, gave plenty of steam and involved no trouble, the automatic feed working very reliably. The mean results of the eight-hours' trial are recorded in Table II, and it will be seen that the steam pressure at the boilers was 202 pounds and at the engines 173 pounds. The cylindrical

boilers required an air pressure of 0.7 inches, and even then did not maintain their fair proportion of steam at full pressure. The vacuum was 25.75 inches, and the average power for the eight hours was 21,489 indicated horsepower. The coal consumption worked out to 2.29 pounds per indicated horsepower per hour.

After the steam tests were over, the vessel was put through a number of maneuvers, and the steering gear (fitted by Messrs. Napier Brothers, limited, of Glasgow) was tried. There are two sets of vertical engines located in the engine room. They operate through shafting a screw with a right- and left-handed thread, on which are nuts connected to the crosshead on the rudder head. Special note was taken of the smooth running of the steering engines and of the facility with which the one was uncoupled and the other put in gear after the orders were given. One of the engines ran the rudder over from the center line to hard-a-port in 10 seconds, while the other engine ran the rudder over from hard-a-port to hard-a-starboard in 18 seconds, both very satisfactory results. Circling trials were conducted and other maneuvers and tests made.

THE STEAM TRIALS OF H. M. SS. *ANTRIM* AND *DEVONSHIRE*.

Two more of the armored cruisers of the *Devonshire* class have now passed through their trials, attaining in each instance very satisfactory results, and demonstrating that, although the legend speed was only 22¼ knots, all of the vessels will attain 23 knots, largely as the result of recent experience regarding the proportions of propellers. The first vessel tried—the *Carnarvon*, built by Messrs. William Beardmore & Co., Limited, Dalmuir, (see p. 430) attained a speed of 23.3 knots with 21,322 indicated horsepower. The *Antrim*, built and engined by Messrs. John Brown & Co., Limited, of Clydebank, steamed at 23.02 knots for 21,606 indicated horsepower, and the *Devonshire*, built at Chatham, and engined by the Thames Iron Works Shipbuilding and Engineering Company, Limited, made 22.97 knots for just over 21,000 indicated horsepower.

In these vessels comparative tests are being made as to the efficiency of propellers, and for this reason the speed results are interesting. We gave in our record of the *Carnarvon* trials (page 442) the details of the measured-mile runs, and now we give in Table I the corresponding records of the measured-mile runs by the *Antrim*. In practically all the vessels of the class the propellers are three-bladed, with a diameter of 15 feet 9 inches, and a normal pitch of 19 feet 6 inches. There is, however, a difference in the expanded surface. The *Carnarvon*, for instance, has a total blade surface of 80 square feet, whereas in the case of the *Antrim* it is 75 square feet. Probably, as a direct result of this, the speed of the *Antrim*, as shown in Table I, was 21.33 knots, when the engines were developing 14,643 indicated horsepower, whereas in the case of the *Carnarvon* it was 21.43 knots for 15,351 indicated horsepower; so that the assumption is that at this speed the larger surface propeller was not quite so efficient. At full power, however, although the *Antrim* indicated about 300 horsepower in excess of the power developed by the *Carnarvon*, her speed was considerably lower. The *Carnarvon*, which has proved herself thus far the fastest cruiser of the class, made

Table I.—RESULTS OF MEASURED-MILE SPEED TRIALS OF H. M. S. *ANTRIM.*

Number of runs.	Revolutions per minute.		Indicated horse-power.		Total.	Speed, knots.
	Star-board.	Port.	Star-board.	Port.		
Four Runs on 14,000 Indicated-Horsepower Thirty-Hours' Trial.						
1	125.6	129.6	7,097	7,591	14,688	20.88
2	128.3	129.3	7,233	7,173	14,406	21.92
3	129.6	129.3	7,773	7,178	14,951	20.69
4	131	129.6	7,533	6,995	14,528	21.94
Mean of means.....	128.7	129.4	.....	.....	14,643	21.33
Four Runs on Full-Power Eight-Hours' Trial.						
1	143.3	143	10,698	11,180	21,878	23.31
2	143.3	143	10,664	10,914	21,578	22.99
3	145.3	142	10,928	10,903	21,831	22.88
4	142.3	142.6	10,419	10,718	21,137	23.23
Mean of means.....	143.8	142.6	.....	.....	21,606	23.02

23.3 knots for 21,322 indicated horsepower, while the *Antrim* for 21,606 indicated horsepower steamed at 23.02 knots.

Another interesting fact in connection with the class is, as we pointed out in connection with the *Carnarvon*, the variation in the types of boilers used. In the first place, a considerable portion of the steam-generating plant is of the cylindrical boiler type; and, in view of the remark made by one of the speakers during a discussion at the recent meetings of the Institution of Naval Architects, it may be noted that comparative trials, in one of the ships now fitted with a proportion of cylindrical and water-tube boilers, have shown that this arrangement, proposed by the Boiler Committee, and now happily departed from, has involved a material reduction in the speed of some of our ships. One of the *King Edward VII* battleships, which has the combination system, was ordered to run four trials of eight hours' duration in order to test the comparative evaporation of the same proportion of cylindrical and Babcock & Wilcox boilers. The first trial was with Babcock & Wilcox boilers, equal to one-fifth total power, and the second with cylindrical boilers, also equal to one-fifth of the total power. It was found that whereas the former gave 3,759 indicated horsepower, the tank boilers only gave 3,634 indicated horsepower; the coal consumption was 1.74 pounds and 1.8 pounds per indicated horsepower per hour respectively. The third trial was with all the cylindrical boilers working under full-power trial conditions, under an air pressure not exceeding 1 inch; while the fourth trial was with an equal proportion of boilers of the Babcock & Wilcox type, burning an equal amount of coal to that used by the cylindrical boilers in the third trial, and run so as to attain as high a power as possible. The cylindrical boilers were supposed, when the design was prepared, to be equal to two-fifths of the full power—namely, 7,200 indicated horsepower; but on this special trial, when worked at an air pressure of 0.96 inch, it was found that the total power got was only 6,686 indicated horsepower, showing that they were deficient to the extent of nearly 10 per cent. The total coal burned on the eight hours' trial

was 100,890 pounds, equal to 1.88 pounds per indicated horsepower per hour. An equal proportion of Babcock & Wilcox boilers, working at the same power, and burning in the eight hours 100,498 pounds of coal, the air pressure in the stokehold being 0.8, gave 7,510 indicated horsepower, which was 300 more than was anticipated, while their coal consumption was only 1.67 pounds per indicated horsepower per hour. In other words, for the same coal consumption, the water-tube boilers gave over 12 per cent. more power, and the ratio of consumption to power was 0.21 pound less per unit of power per hour = 11 per cent. less than with the tank boilers.

The boiler installation of the *Antrim* is a combination of the Yarrow type and cylindrical boilers. In the forward boiler room there are five, and in each of the two middle boiler rooms six, Yarrow type boilers, making in all seventeen Yarrow type boilers, having a grate area of 869 square feet and a heating surface of 49,077 square feet. The after boiler room contains six cylindrical boilers, having a grate area of 313 square feet and a heating surface of 9,366 square feet. Both the Yarrow type and the cylindrical boilers are arranged to work with Howden's system of forced draft. Two Weir's feed pumps are fitted in each boiler room. In each of the three forward stokeholds there is a See's ash ejector, and in the after stokehold an electrically-driven ash hoist. The fans for the forced-draft system are twenty in number, and are driven by by enclosed steam engines worked with forced lubrication. The air-pressure and coal-consumption results of the *Antrim* trials are recorded in Table II, along with other details. In the high-power runs the evaporation per pound of coal was over 8 pounds. From first to last everything worked most satisfactorily, alike as regards the boilers and their machinery. On the full-power trials the mean power was 21,604 indicated horsepower, which was 604 indicated horsepower in excess of the guarantee; while on the thirty hours' trial, when, according to contract, the power was to average 14,000 indicated horsepower, the mean attained was 14,628 indicated horsepower, with a coal consumption of 1.95 pounds per indicated horsepower per

Table II.—STEAM TRIALS OF H. M. S. *ANTRIM.*

	30 hours. One-fifth power coal consumption.		30 hours. 14,000 indicated horsepower.		8 hours. Full power.	
	Forward.	*Aft*	*Forward.*	*Aft.*	*Forward.*	*Aft.*
Draught of water, feet and inches	24– 8	25– 7½	24– 7½	25– 6¾	24– 7	25– 7
Steam pressure in boilers, pounds	161		186		185	
			Trunks.	*Ashpits.*	*Trunks.*	*Ashpits.*
Air pressure in stokeholds, cylindrical boilers, inches	0.2		0.98	0.65	1.77	0.75
water-tube boilers, inches			0.9	0.4	1.66	0.78
	Starboard.	*Port.*	*Starboard.*	*Port.*	*Starboard*	*Port.*
Vacuum, inches	25.4	25.5	25.5	25.1	25	25
Revolutions	88.4	87.7	127.8	127.4	142.6	142.6
Mean pressure in receivers, high, pounds	104.1	103.6	158.3	159	163.7	166
intermediate, pounds	12.6	13.5	46.5	48.1	52.7	55
low, pounds	10.2	6.18	8.5	6.75	14	15
cylinders, high, pounds	39.22	38.12	67.4	64.5	81.15	82.6
intermediate, pounds	11.99	12.05	26.6	25.4	30.75	32.5
low, forward, pounds	3.79	3.77	11	11	15.8	16.7
aft, pounds	3.70	3.84	10.9	10.8	16.7	16.64
Mean indicated horsepower, high	995	960	2,472	2,358	3,321	3,383
intermediate	758	756	2,426	2,325	3,135	3,315
low, forward	302	299	1,271	1,272	2,026	2,143
aft	295	303	1,258	1,246	2,145	2,136
Total indicated horsepower	2,350	2,318	7,427	7,201	10,627	10,977
Grand total	4,668		14,628		21,604	
Coal consumption per I.H.P. per hour, pounds	2.06		1.95		2.26	
Water consumption (including auxiliary engines) per hour, pounds	18,451		16.48		18.25	
Loss of water per 1,000 I.H.P. per 24 hours, tons	2.2		1.7		2.5	
Total loss of water, tons	12.86		31.75		18	
Speed of ship, average throughout trial, knots	.....		21.1		22.92	
mean of four runs on measured mile, knots	.....		21.33		23.02	

Table III.—RESULTS OF STEAM TRIALS OF H. M. ARMORED CRUISER *DEVONSHIRE*.

	March 13 and 14, 1905. 30 hours' coal and water consumption at 4,500 indicated horsepower.		March 22 and 23, 1905. 30 hours' coal consumption at 14,700 indicated horsepower.		April 7, 1905. 8 hours' full-power trial.	
Date of trial						
Nature of trial						
	Forward.	*Aft.*	*Forward.*	*Aft.*	*Forward.*	*Aft.*
Draught of water, feet and inches	24- 6	25- 6	24- 6	25- 6	24- 6	25- 6
Speed, knots	13.07 by bearings.		21 by log.		22.97 mean of four runs.	
Steam pressure in boilers, pounds per square inch	159		193		200	
Air pressure in stokeholds, inch	.....		.....		.595	
	Starboard.	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*
Vrcuum in condensers, inches	25.2	23.8	25.6	25.9	24.6	25.3
Revolutions per minute	83.8	83.4	126.7	126.8	139.55	140.45
Mean pressure in receivers, high, pounds	110	101	165	161	179	179
intermediate, pounds	21	20	45	45	64	65
low, pounds	3	2	8	9	20	19
Mean pressure in cylinders, high, pounds	33.6	36	70	70.4	85	81.8
intermediate, pounds	13.2	13.05	24.8	26.2	30.9	31.9
low, fore, pounds	4.6	4.07	10.3	10.7	15.4	15.5
aft, pounds	4.53	4.02	11.5	12.1	17.95	18.5
Mean indicated horsepower, high	810	862	2,548	2,564	3,405	3,295
intermediate	787	778	2,249	2,374	3,081	3,200
low, fore	347	305	1,176	1,225	1,935	1,962
aft	342	302	1,310	1,384	2,255	2,342
Total indicated horsepower	2,286	2,247	7,283	7,547	10,676	10,799
Grand total	4,533		14,830		21,475	
Coal consumption per I.H.P. per hour, pounds	2.05		2.023		1.79	
Total loss of water during trial, tons	18.1		52.64		18.82	

hour, and a water consumption of 16.48 pounds. In the ships with the Yarrow type boilers it was decided that the power on this thirty-hours' trial should be 14,000 indicated horsepower, against 14,700 in the ships with other types of boiler.

In the *Devonshire*, the prototype of the class, the boilers are of the Niclausse type—fully dealt with in connection with the *Carnarvon*. After the second thirty-hours' trial, however, the boilers of the *Devonshire* were modified, baffles being fitted in the steam drums, which effected a marked improvement, as is indicated by the reduced coal consumption on the full-power trial, and also by the reduction in loss of water during the trial. The vessel was designed to develop 25,000 horsepower; but, as is shown, she maintained during the eight-hours' run a mean of 21,475 horsepower. The four runs over the measured mile were made at about the normal power, and the speed was 22.97 knots. The results on all three trials are tabulated in Table III.

As in our article (see p. 430) we fully described the main characteristics of design of ship and engines, it is not necessary here to do more than give the leading dimensions. The length between perpendiculars is 450 feet; the breadth, molded, 68 feet 6 inches; the depth, molded, 38 feet 6 inches, and the mean draught 25 feet, at which the displacement is 10,850 tons. The vessels are fitted with four 7.5-inch and six 6-inch quick-firing guns, along with twenty-five smaller weapons. The engines are of the triple-expansion four-cylinder type, now almost universally adopted in cruiser work, and the diameters of the cylinders are: High pressure, 41½ inches; intermediate, 65½ inches; and two low-pressure, 73½ inches; all having a stroke of 42 inches.

The trials of the *Antrim* and *Devonshire*, as of the *Carnarvon*, were carried out under the new regulations, which require that the staff employed and the general arrangement agree exactly with the service conditions. All bulkhead doors were shut, and the engines were run with limited clearance in the bearings, and without water. The running of the machinery and the general results in all cases were highly satisfactory.—"Engineering," London, April 28, 1905.

A CHANGE IN BATTLESHIP CONSTRUCTION.

By G. E. R. (From "Ueberall," No. 15, April 7, 1905.)

* * * I have previously spoken of the tendency of the intermediate battery towards considerably larger calibers, and derived the conclusion that the new German battleships also should have a larger medium-caliber gun, while retaining for the present the four 28-cm. guns of the main battery. But in the meantime a view which actually urges the adoption of the 30.5-cm. caliber for the main battery has been gaining more and more ground in England and appears to have prevailed. No doubt a material change in the English battleship type is impending, one indication in that direction is the circumstance that nothing has become public as regards the names and data for the new ships which are to follow the *Lord Nelson* class.

The *King Edward* class as well as the two ships of the *Lord Nelson* class are the results of a period of groping and experimenting in English battleship construction. Especially the ships of the *King Edward* class, with their three different medium and large calbers, are by no means ideal from the point of view of armament, and we may say without hesitation that their fighting efficiency is very low as compared with their displacement. Compare them, for instance, with the very much smaller ships of the German *Braunschweig* class. That does, of course, not alter the fact that, taken absolutely, the *King Edward* is considerably superior to the *Braunschweig*. Even in England many unfavorable opinions may be heard concerning the *King Edward* class as also the *Lord Nelson* class, especially in technical circles, while the press, of course, as usual and in accordance with its principles, lauds and exaggerates the advantages of the English ships over those of other nations.

Several months ago the head of the well-known shipbuilding firm of Vickers made a speech—if I remember right, on the occasion of a launching—in which he referred to the battleship of the future. He said, among other things, that in his

opinion the ideal type of battleship was one with a battery of ten 30.5-cm. guns and a speed of over 20 knots. The armor protection would, of course, have to be accordingly. In the course of the last few months several superior officers of the English Navy, as also the former First Lord of the Admiralty, Lord Selborne, and the Civil Lord, Lord Lee, have all expressed the opinion that England would in future build only battleships which it would be impossible to surpass in power of armament. Combining all these indications, it may be pretty safely assumed that a battleship having 30.5-cm. guns exclusively is being seriously considered in England, and that the plans for the same have been probably fully worked out. From the point of view of armament there can be nothing beyond that, since it has so far been the general opinion that the 30.4-cm. caliber is the largest that can be used to good advantage on board of warships.

The chief objections to such a uniform armament may be summed up as follows: The rapidity of fire is lower under all circumstances than that of the smaller calibers; a broadside, or firing all of the turret guns, at the same time, is therefore, to a certain extent, precluded. Speaking purely from a military standpoint, each shot from a large gun represents a comparatively greater event and a failure to hit a greater mishap than in the case of smaller calibers. A large gun can stand at best one hundred rounds; after that it becomes useless. Moreover, the ammunition for such a gun takes up so much space and weight that the allowance per gun can be but small. It follows that the whole battery, whether for the first reason or for the last, can function only for a shorter space of time than the strong medium-caliber battery. Hence, for a ship armed exclusively with large guns it is imperative that she should accomplish her military mission—that of disabling her adversary—before the technical exhaustion of her firing efficiency. And this in its turn entails the principle, both strategically and tactically, of offensive carried to the utmost. An undecisive action, which does not disable the eneny will no

longer be admissible if the 30-cm. gun ships wish to keep within the limits of the efficiency of their guns.

A very forcible illustration on this point is furnished by the recent exchange of the 30.5-cm. guns on board the English *Majestic* class, mentioned on page 279 of the last number of this publication. These ships have completely worn out their guns in the course of a few years, merely by target practice. It may be assumed under all circumstances that, no matter when a war may break out, nearly all the ships of the fleet will go into action with their heavy guns more or less impaired, for target practice with full-caliber ammunition can not be restricted, not even in the case of the heavy guns, especially in view of recent experiences, which have shown that battles at long range have very good prospects of success. To render such long-range battles decisive—using the term to designate ranges beyond the zone of danger from torpedoes—is the very object striven for in arming battleships exclusively, or almost exclusively, with large guns. No doubt such ships will also be very heavily armored, and so the other nations will be compelled to follow in the same footsteps as regards their new types of battleships. If they do not, the English battleships would be able in a short time, by powerful offensive, to bring about a decision in their favor. Their guns have higher perforative power and higher explosive power. They can fire effectively at the more lightly armed and less powerfully protected hostile ships at ranges where the latter will be unable, with their medium-caliber guns, even those of 24 cm., to inflict any injury upon them. Within a very large zone the present intermediate battery would thus be wholly ineffective, and there would remain only the main battery, consisting on board the German battleships of four 28-cm. guns. These would be opposed by ten 30.5-cm. guns, and the issue would not be doubtful, even if two German ships were confronting one English ship. Hence we shall have to follow suit.

It is ardently to be hoped that the new battleships to be asked for in the fall of next year will be armed with eight to ten 28-cm. guns in place of four. There is no reason why we

should abandon this caliber and substitute a larger one, since the difference in efficiency between the 30.5-cm. and the 28-cm. gun is comparatively small, while, on the other hand, there would probably be a very great saving in weight, which, with equal displacements, could be utilized in favor of the ammunition supply, the armor, etc. Whether it is a good plan to renounce entirely the intermediate battery, as the English have done in the *Lord Nelson* class (in this case the armament consists of four 30.5-cm. and ten 23.4-cm. guns), is open to discussion. While the medium-caliber guns—that is, up to 20-cm.—can, under present and future conditions, no longer claim to have armor-piercing effects, modern ships have now, and will have in future, so many unprotected parts, especially as regards the superstructures, that it would seem risky to relinquish the fire of explosive shell and rapid-fire broadsides. That was plainly demonstrated in the battle of August 10th. Moreover, there will always be cases where battleships will be called upon to fire at inferior foes, such as cruisers, for instance. As against these medium-caliber guns would be sufficient, and a battleship which no longer carries them would be obliged to allow her large guns to be impaired. That would be against the law of rational economy of forces. The same applies also to actions of battleships among themselves.

The above mentioned technical defects and dangers of large guns will in all probability not be able to impede the military development. On the other hand, the technical arts will endeavor to eliminate and minimize them. Whether it will be possible to render the raw material more durable is doubtful; for it is not the high gas pressure, but rather the enormous heat generated upon the burning of the powder charge, that causes the rapid deterioration of the material. Attempts to reduce the degree of temperature by different chemical compositions of the powder have so far not been successful as far as known. If no decisive progress is made in these two directions there remains but one expedient for prolonging the life of guns, and that is to decrease the quantity of the powder charge. It is true that this would result in a reduction of the

power of perforation of the projectile, and we shall probably have to put up with that, for the disadvantage of a decrease in perforative power is small as compared with the advantage gained by enabling the gun to withstand a considerably larger number of rounds. New inventions in the field of the technical arts in question may, of course, upset the foregoing chain of reasoning in a minute and put new points of view in its place. In England a definite course has probably already been decided upon. This may be inferred from a recent remark in a service paper, which expresses its satisfaction over the fact that a very high rapidity of fire has been reached, even for the largest guns. It is on the solution of these questions, after all, that the whole new type and its efficiency will depend. It is highly probable that the experience of the *Majestic* class has not failed to produce its effects upon the English naval authorities.

But the more rounds the large guns are able to fire the more difficult and important becomes the question of ammunition supply. We speak now of a coaling strategy—that is, a strategy based on the possibility of keeping the fleet constantly supplied with coal, and the war in East Asia in all its phases has shown the importance of it. Something similar will in future apply also to the ammunition supply, and the replenishing of the ammunition expended from naval bases, or the taking along of ammunition ships will form one of the most important questions of future wars. Another point not to be overlooked is the change in the ship's draught caused by the considerably increased consumption of ammunition. This must, of course, be added to the coal consumption, and the total will be so great that the armor of the waterline will have to be made considerably wider. Even in the present war, Russian battleships, as well as armored cruisers, have sustained leaks below the narrow armor belt as the result of hits, and that will be the case to a much greater extent when a battleship with large, uniform-caliber guns has consumed large quantities of ammunition and coal. The danger is further enhanced by the fact that a 30.5-cm. projectile which strikes the water near a

ship has a much better chance than a lighter one of penetrating the water and striking the unprotected part of the ship's side. Whether this difficulty should be met by widening the outer armor belt or by particularly careful subdivision into cells and a thin inner armor below the waterline are technical questions which can be decided only by a combination of theoretical computations and practical experiments.

The outer appearance of these battleships of the future will differ materially from that of our present battleships, especially as regards the upper parts. The central casemate for the medium-caliber guns, which has hitherto occupied the whole central part of the ship, will vanish entirely or in part, and its place will be taken by the heavy-armored turrets for the 30.5-cm. guns. In a certain sense this would mean a reduction of the easily vulnerable surfaces. The large, massive superstructure would disappear, making the target perhaps somewhat lower; but the forward and after conning bridges will probably have to be kept at the same level as at present, and they will also have to be connected with each other by the so-called light flying bridge, which passes above the two turrets between them. The suitable arrangement of the inner spaces will present decided difficulties. Considerable space will be lost, on the one hand, by the absence of part of the upper superstructures, which will be necessary in order to afford the large turrets the requisite arc of fire, and on the other hand, also below deck, where the bases of the turret, which must be carried through to the protective deck, will take up considerable space. Thus the quartering of the officers and men will probably prove very difficult.

From all the foregoing it follows that the displacement of such battleships will have to be very large, and further, that, notwithstanding the very moderate confines of the new naval programe, their cost will be very considerable. An industrial paper has computed the additional cost, as compared with our present displacement of 13,200 tons, at 8,000,000 marks per ship. I am not in a position to verify this estimate in detail, but it is probably not very far out of the way. Our present

battleships cost about 25,000,000 marks each, so that the increase in cost will amount to about one-third of the sum heretofore required, and will correspond to a displacement of 16,000 tons.

THE FRAHM SPEED INDICATOR.

By Friederich Lux.

The Frahm Speed Indicator is based on the employment of the *principle of resonance.* This, as is well known, is the property that elastic bodies possess of being set in vibration, if they are subjected to rhythmic impulses, the frequency of which corresponds with the natural period of vibration of the bodies themselves.

Resonance may be manifested wherever wave motion occurs, as, for instance, with sound, light and electricity. The effects of resonance in accoustics are well known in connection with musical instruments. The fibers of Corti in the ear are an interesting example of elastic bodies set in vibration through resonance. In the case of wireless telegraphy, one of the most modern scientific developments, electrical resonance plays an important part.

The destruction of the Suspension Bridge at Angers, on the 16th April, 1850, by which 226 French soldiers lost their lives, proved a disastrous instance of the effect of resonance.

The investigations undertaken by Mr. Hermann Frahm on the torsional vibrations in propeller shafts have clearly proved that resonance in this connection may have a most momentous effect. Mr. Frahm, however, did not cease his investigations when he had found a means of suppressing the dangers of resonance, but he went further and developed the idea of usefully employing the same principle for the purpose of measuring velocities. His experiments resulted in the discovery of his present form of speed indicator.

The fundamental part of the Frahm Speed Indicator, of which there is a full size illustration in Fig. 1, consists of a spring of best watch-spring steel or other elastic material, the dimensions for ordinary purposes being 40 to 55 mm. long, 3

mm. wide and 0.25 mm. thick. These sizes permit of a convenient employment of the apparatus, and are sufficient for most practical cases. They may be varied in accordance with any special application.

Fig. 1.

The springs are set in a slit cut in a small rectangular shoe, to which they are firmly pinned and soldered. At its upper end each spring is bent over at right angles for about 4 mm., and the head thus formed is covered with white enamel so as to render it easily visible. In the angle which the head makes with the stem of the spring is placed a small drop of solder. The number of vibrations such a spring will make depends primarily on the length of the vibrating part and the weight at the head, as it is made of a material as uniform as possible in quality and thickness. Thus, if the springs have a stem of 40 to 55 mm. long, and more or less solder is attached to the head, any desired period between the limits of 35 vibrations per second and 100 vibrations per second can be obtained.

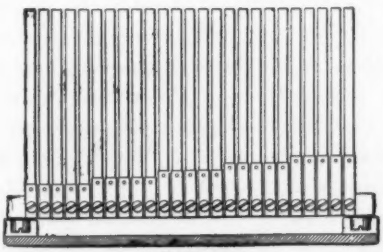


Fig. 2.

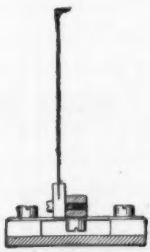


Fig. 3.

An assemblage of such springs attuned to various periods is illustrated in figures 2 and 3. They are screwed to a bridge consisting of an iron or brass rod 6.5 mm. square, and are spaced at a distance of 1 mm. from each other. This arrangement,

somewhat resembling a comb, forms a self-contained system for certain limits of measurement. The length of the comb is, so to speak, unlimited. It might be made as much as one meter or more, and contain 100 units of attuned springs, but in most cases a comparatively small number is taken, for example, 25 to 50, while in other circumstances 3 or 5 are quite sufficient.

This comb is fixed on two end plates of springy material, screwed to supporting feet, so as to permit the bridge to have a small vibrational movement at right angles to its axis. When only a very small number of springs is used, one such bridge is sufficient, and this, under certain circumstances, may be fixed at one side only. In other cases this elastic support is not necessary, and the comb can be placed directly on the spot where it is desired to measure the vibrational movement.

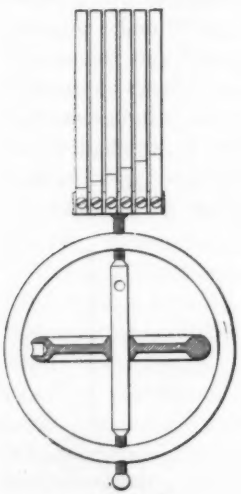


Fig. 4.

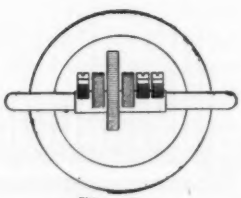


Fig. 5.

The comb can be set in vibration in various ways. The simplest of these is to place it (either with or without the end plates) direct on the frame of the machine, the speed of which has to be measured.

As it is a matter of difficulty to keep the center of gravity of a rotating system exactly and permanently in the axis of rotation (except, perhaps, in the case of elastic shafts, as in the De Laval turbine), the bed plate and frame of all running machines are subjected to more or less strong vibrations.

These vibrations are in many cases quite sufficient to actuate one of the springs of a comb touching the frame of the machine, and the amplitude of the vibration may reach from 2 to 30 mm., according to the eccentricity of the center of gravity.

A pretty experiment, in illustration of this, may be made with an ordinary gyroscope, by placing a small comb of springs on one of the pivot screws.

With such a cheap apparatus as the gyroscope, it is naturally impossible to guarantee that the center of gravity will lie exactly in the axis of rotation, and, as a rule, it is a good deal out of true, so that the vibration of the springs may have an amplitude of from 40 to 50 mm. Should the center of gravity be very little out of the axis, all that is necessary for the experiment is to cut a small hole in the outer rim of the revolving disc, when a strong effect will be shown on the springs.

Fig. 5 illustrates the appearance of the apparatus as seen from above.

With a machine running at a speed of over 1,000 revolutions per minute, as for instance, a steam turbine, Pelton wheel, fan, or milk separator, a practised eye, accustomed to scientific work in a laboratory, would find an amplitude of 2 mm. or even less quite sufficient for reading off the speed, when the comb is placed directly on it. For practical purposes, where it is necessary to stand two or three yards from the machine, this amplitude would be insufficient, and 20 to 30 mm. at least must be obtained. To do this it is in most cases necessary, except for badly-fixed or irrregularly-running machinery, to have special means for setting the springs in vibration.

The second and the simplest method for the production of vibrations is to employ a tappet wheel or cam.

For example, such a cam, with a number of elevations and

depressions on its periphery, is fixed on the shaft the speed of which it is desired to measure, and works against a lever, which is thereby caused to vibrate. The vibrations can be transmitted to one of the combs above described by placing it directly on the other end of the lever, or it may be connected with the lever by means of a rod, wire or string.

Fig. 6.

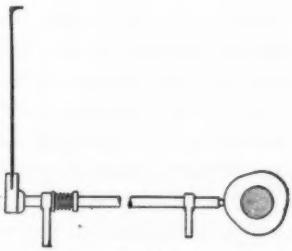


Fig. 7.

In figures 6, 7 and 8 are illustrated these three methods of communicating the impulses to the springs, and by their employment it is possible to make the distance of transmission up to 10 meters.

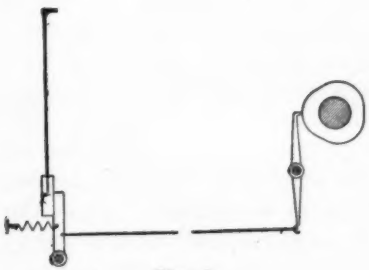


Fig. 8.

Should it be necessary to measure the speed of a machine at greater distances, it is better to employ electrical transmission. The following is one method of affecting this:

On the bridge of the comb (Figs. 9 and 10) parallel to the springs is fixed a piece of soft iron in the form of a flat bar, which forms the armature of a magnet, on the poles of which two coils are wound.

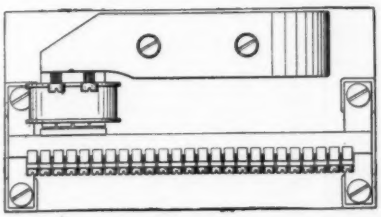


Fig. 9.

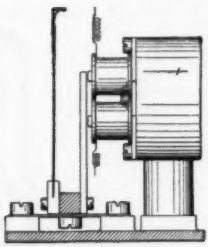


Fig. 10.

If, now, an alternating current is passed through these coils, the armature will be regularly attracted and repelled, so that the comb is made to vibrate in correspondence with the frequency of the current. All the springs are made to quiver slightly at their lower ends, just as above described, and that particular spring whose natural period of vibration is most nearly in unison with the actuating impulses, will be set into very strong vibration, its amplitude depending on the more or less close agreement of its natural period with that of the actuating device.

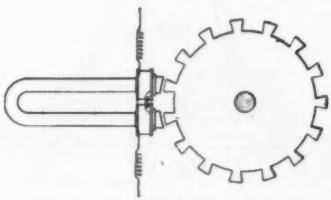


Fig. 11.

If we wish to employ this method to determine the speed of an alternator, all that is necessary is to connect these magnet coils through a resistance to any convenient point in the network. The speed can then be read off directly, as the frequency is a simple multiple of the speed.

Should it be desired, however, to measure the speed of a machine which does not furnish alternating currents, we must use a special alternating-current generator, which can be driven from the machine in question.

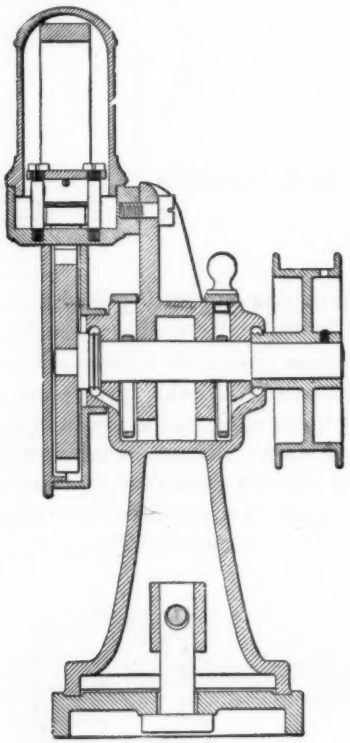


Fig. 12.

A generator of the simplest form for this purpose (Fig. 11) consists of a toothed disc of soft iron, which rotates close to the pole pieces of a permanent magnet, on which are wound two small coils. This revolving armature may either be fixed direct to the shaft, the revolutions of which it is desired to measure, or the driving power may be transmitted from the shaft to the revolving inductor by means of a small belt.

Figures 12 and 13 illustrate an alternator of the type which we have frequently employed where the revolving inductor can be connected directly to the shaft. This apparatus may be called the transmitter (using the same terminology as in telegraphy or telephony). Its circuit is connected either by

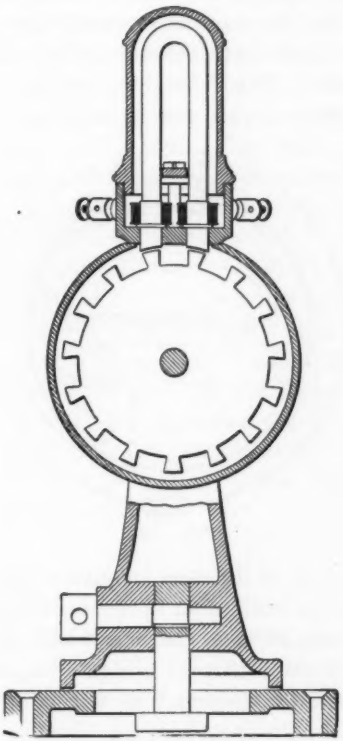


Fig. 13.

two wires or one wire and an earth return to another apparatus, illustrated in Fig. 14, called a receiver, which indicates by its vibrating springs the velocity at any instant.

Instead of an alternating current, an interrupted continuous current can be used to actuate the apparatus, by using one

of the well-known forms of continuous current interrupters, driven by the machine.

From the foregoing it will be obvious that the vibrator, which is actuated electrically, may be made to serve very conveniently for determining the frequency of an alternating-current or the interruptions per second of a continuous-current circuit, and thereby determine the number of revolutions per minute of any machine or shaft at any distance, either with or without a special transmitter. It will be clear also that one transmitter can simultaneously operate several receivers.

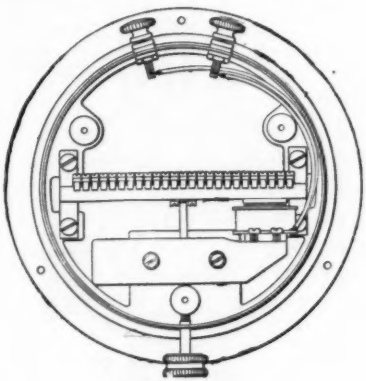


Fig. 14.

Further, as waves of different frequency and amplitude can be superimposed on each other in one conductor and analyzed in the receiver, one receiver can at one and the same time be actuated from several different places. In this way it is possible to compare the frequency of two or more alternating currents.

Frahm's indicator may thus be used for paralleling alternators and polyphase generators, or as a phase indicator, or for the determination of the slip of an induction motor.

It also permits of the observation and supervision at one place of the running of any number of machines, and gives a centralization of the work's management in this respect in a way that was previously undreamt of.

The long-continued experiments and investigations conducted by Mr. Frahm at the shipyard of Messrs. Blohm & Voss at Hamburg, where he acts as Chief Engineer, have demonstrated that the natural periods of the springs, and therefore the indications of the apparatus, do not vary in the least with the lapse of time, even in the case of apparatus which have been working continuously for nearly two years. Single springs, particularly those which correspond to the normal indication, have during this period made more than one hundred million vibrations, but they have not experienced any detrimental change and possess today their original natural period. The number of vibrations per second is not in the least influenced by the manner in which the impulses are set up, nor by the amount of the movement of the cam, nor by the nature of the electrical transmission. In the latter case the degree of accuracy of the indications is not affected by the variation in the resistance of the conducting wires nor the voltage of the magneto-generator. In fact, the accuracy depends solely on the frequency of the impulses.

Thus Frahm's apparatus embodies the ideal of an absolutely accurate speed indicator, uninfluenced by external conditions and as true in its indications as the natural law which its mode of working exemplifies.

RECENT PERFORMANCE OF THE *TARANTULA*.

The following notes were furnished by Commander R. S. Griffin, U. S. N., member.

On the 9th of May the turbine yacht *Tarantula*, belonging to Mr. W. K. Vanderbilt, Jr., made a short run in Long Island Sound, which was attended by representatives of the Bureau of Steam Engineering of the Navy Department, for the purpose of obtaining information additional to that obtained from the trials of the same yacht last year, and described on page 1095 of Volume XVI. Before starting it was the intention to make several runs at various speeds, but owing to a slight mishap to one of the shaft struts, the extent of which could not

be readily determined, it was deemed prudent not to make runs at lower than full-power speeds, the mishap referred to having become apparent when about to begin a run at a speed of about 18 knots.

The full-power runs, one in each direction, were made between the Stepping Stones and Execution Rocks, a distance of $3\frac{3}{8}$ nautical miles. During both runs there was an ample supply of steam, and, except for the very poor vacuum, a condition noted on her trials last year, the machinery as a whole worked in a very satisfactory manner.

The principal data were:

Speed, knots	23.03
R.P.M. center shaft	1,167
starboard shaft	1,074
port shaft	1,085
Steam in boilers, pounds, by gauge	274
H.P. casing, pounds, by gauge	269
I.P. casing, pounds, by gauge	77.7
L.P. casing, pounds, by gauge	1.8
Vacuum, inches	21.3
Temperature of hot well., degrees	115
Air pressure, in inches of water	$4\frac{1}{4}$

Several changes have been made in the machinery since the trials of last year; the most noteworthy being the removal of two Yarrow boilers and the substitution of two of the Mosher type, by which change the grate surface was increased from 66 to 120 square feet and the heating surface from 3,680 to 5,620 square feet. The general design of this boiler follows that of the monitor *Florida*, illustrated in the JOURNAL on page 563 of Volume XV, except that there is a feed-water heater where the baffle of non-conducting material is shown; that the gases pass outward below the line of the heater, and that there are no outside down-comer pipes. One other feature that calls for special mention is the provision for removing tubes. In the upper half of the steam drum there are plugged holes on either side, through which it is possible to remove or replace a tube. The feed-water heater is composed of curved headers, into which nests of tubes are expanded, there being diaphragms in

the headers to so direct the flow of water that it shall be continuous from the bottom to the top. The water enters the steam drum at the front end and discharges into internal pipes running the length of the drum. These pipes are perforated opposite each tube of the outer row so that the discharge from them will be directed downward and assist the circulation.

One other important change was the substitution of Blake "featherweight" air pumps for the original pumps driven from the center shafts; but this change, as noted above, has not been attended by any improvement in the vacuum. The new pumps are 6 by 12 by 8 inches.

Two Sirocco fans have been fitted instead of the original Sturtevant fan, and an additional auxiliary circulating pump has been connected with the port condenser.

THE CORROSION OF COPPER IN SEA WATER.

We give below a translation of an article written by Herr Uthemann, Privy Councillor to the German Navy, on a number of interesting experiments which this gentleman has been carrying out with a view to discovering an effective means of protecting copper and its alloys against corrosion through the action of sea water.

Copper and its alloys, says Herr Uthemann, have been used in shipbuilding for a long time, and are considered to be valuable materials in the various branches on account of their suitability and adaptability to this industry.

In 1761 the English Admiralty had commenced to protect their ships with copper plates as a preventive to the adhesion of shells to the hulls, and soon afterwards the use of copper for the internal construction of ships increased proportionately to the development of steam engines as driving power. The physical properties of copper and bronze facilitated the manufacture of various parts and fittings both in ships and their engines, and no other material of similar qualities specially suitable for pipe lines was known at that time. Demands for greater speed of vessels were continually made, necessitating

I.—IN FLOWING WATER.

Number of trial.	Days.	Material.	With or without iron protection.	Increase or decrease per 1 sq. cm. of area in mg.	Remarks.
1 *a*	94	H-copper	With	+ 346.00	Water with 3.5 per cent. common salt. Temperature + 13 deg. C.
1 *b*	94	H-copper	Without	+ 40.25	
2 *a*	52	H-copper	With	+ 411.00	Water with 3.5 per cent. common salt. Temperature + 16 deg. C.
2 *b*	52	H-copper	Without	+ 161.00	
3 *a*	30	E-copper	Without	— 106.50	Water with 3.5 per cent. common salt. Temperature + 16 deg. C.
3 *b*	30	E-copper	Without	— 173.30	
4 *a*	187	E-copper	With	+ 700.70	Water with 3 per cent. common salt and 0.5 per cent. magnesium chloride. Temperature + 18 deg. C.
4 *b*	187	E-copper	With	+ 845.30	
5 *a*	187	E-copper	Without	— 522.70	Water with 3 per cent. common salt and 0.5 per cent. magnesium chloride. Temperature + 18 deg. C.
5 *b*	187	E-copper	Without	— 733.40	

II.—IN STILL WATER.

1 *a*	59	E-copper	With	— 441.30	Bath: Water with 3.5 per cent. common salt and muriatic acid 0.8 per cent. Temperature + 5 — 20 deg. C. Spiral only outside.
1 *b*	59	E-copper-brass	With	— 653.60	
1 *c*	59	E-copper-brass	Without	— 3664.50	
2 *a*	33	E-copper	With	+ 71.80	As under 1.
2 *b*	33	E-copper-brass	With	+ 135.70	
2 *c*	33	E-copper-brass	Without	— 88.30	
3 *a*	198	E-copper	With	+ 267.50	Bath: Sea water 3.5 per cent. Temperature + 18 deg. C. Spiral only outside. The cylinders were also covered before the trial electrolytically with a layer of iron.
3 *b*	198	E-copper	Without	— 553.40	
3 *c*	198	E-copper-brass	With	+ 105.30	
3 *d*	198	E-copper-brass	Without	— 4325.00	
4 *a*	74	H-copper	With	+ 20.35	Bath: Sea water 3.5 per cent. Temperature + 22 deg. C. Spiral only outside.
4 *b*	74	H-copper	Without	— 556.00	
4 *c*	74	H-copper-brass	With	+ 1.19	
4 *d*	74	H-copper-brass	Without	— 422.00	
		Condenser tube from—			
5 *a*	74	Heckmann-bronze	With	+ 39.30	Bath: Sea water 3.5 per cent. Temperature + 22 deg. C. Spiral outside and inside.
5 *b*	74	Brass	With	+ 17.90	
5 *c*	74	Heckmann-bronze	Without	— 497.00	
5 *d*	74	Brass	Without	— 300.00	

Remarks.—E-copper = cylinders from electrolytical pure copper; H-copper = cylinders from molten copper; copper-brass = cylinders half copper, half brass, as in Fig. 3.

reduction of weight. This was obtained by using copper, brass, bronze, &c., for such objects which had hitherto been made of cast iron. Not only were cylinder frames and other castings for boiler fittings and pipe lines after that made of bronze instead of cast iron, but also the framework for pumps, condensers and other machinery.

It is significant that at the same time a more pronounced corrosion of thin-shelled brass condenser tubes was noticed, and the Admiralty officials of several nations endeavored to find out the cause of this. Of course, it had been ascertained more than twenty years ago that such deterioration of copper plates which had been attached to sailing vessels and other wooden ships since 1780 took place, but the percentage of such corrosion had increased five to ten fold after 1883. In the "Metallurgy of Stoelzel," Vol. I, "Production of Metals," it is stated: The deterioration of the metal occurred simultaneously with the increased import into England of foreign ore, which necessitated the use of a larger proportion of lead in the melting process. The mixture thus obtained did not stand the subsequent annealing so well, owing to the quality of the copper being impaired. Davy tried to protect the copper plates from oxidation by bringing them into contact with other metals of a more electro-positive nature, such as zinc, wrought or cast iron. He found whenever the area of the protective metal was as $\frac{1}{40}$ to $\frac{1}{150}$ of the copper plates the latter showed neither corrosion nor loss in weight. But it happened that some carbonate of lime and of magnesium occasionally settled down on the surface which subsequently caused fouling by seaweed and shells, thus reducing the speed of vessels considerably. When the ratio of area of protected to unprotected surface was diminished to $\frac{1}{150}$ to $\frac{1}{1000}$ no calcareous or other sediment was observable, and the copper remained, practically speaking, perfectly clean. Although the above process showed satisfactory results during several trials, it was not generally introduced into shipbuilding, and could not have proved to be practical in other respects. Later on Bequerel repeatedly examined the Davy process in his laboratory, as well as on ships in the port

REMARKS.—E-copper = cylinders from electrolytical pure copper; H-copper = cylinders from molten copper; copper-brass = cylinders half copper, half brass, as in Fig. 3.

of Toulon. According to his—Bequerel's—opinion, the failure of the previous trials was due to the fact that the protective metals had to a great extent disappeared, and not sufficient attention had been paid to the disadvantages resulting from the destruction of the oxidizing metals.

Since 1880 it has principally been the condenser tubes which have been destroyed, and later on the copper sea-water mains and other parts of machinery coming in contact with sea water, as, for instance, the circulating-water pumps had these failures, and the difficulty of finding a prompt remedy reduced the use of copper and its alloys to a certain extent; the mercantile marine even went so far as to employ iron more and more, in spite of this material having to be replaced more frequently than copper. A large ocean liner, for instance, which previously used about 35 tons of copper, now only used 10 tons.

As mentioned above, the cause of the corrosion of copper through sea water was explained by its impurities, and specifications only allowed 0.6 per cent. of foreign matter in copper. At the same time various alloys of copper were tried, all with negative results. But even a greater purity of copper did not improve the position. On the contrary, copper made in the ordinary way, and containing a certain percentage of copper protoxide, showed less deterioration than that made by the electrolytic process. From experience we know that very much depends on the composition of sea water and its temperature. In addition to there being a greater percentage of sodium chloride there is an additional proportion of magnesium chloride which seems to act deleteriously, and it has been proved that tropical temperature as well as artificial heating in condensers, &c., especially favors corrosion. Bronze fittings in pipe lines have the tendency to corrode copper with which they come into contact, or to destroy soldered places. The neighborhood of iron also produces pitting, as can be seen whenever copper pipes come in contact with iron plates of the bilge.

The idea that the chemical decomposition of copper in sea water is furthered by electrolytic action seems to be generally

confirmed. It is, however, very unlikely that sea-water mains are in any way influenced or damaged by the action of electrolysis caused by leakage from the electric light and power wires.

Trials to counteract the damaging action of sea water have repeatedly been made, the metals being covered with india-rubber, asphalt, marine glue and other elastic lacquers. One of these, invented by an American named Sabine, has been introduced, and proved satisfactory. Another method which is more widely preferred is the equipment of condensers and pipe lines with zinc protectors. All these methods, however, do not give sufficient protection; in fact, they have so many secondary failings that their general introduction has been restricted. The inside covering of rubber, pitch, &c., can hardly be made sufficiently smooth and free from cracks, and the examination of the same presents considerable difficulty. If part of the tube remains uncovered corrosion will act more intensely at that place. These coverings also decrease the bore of the tube, and with changes of temperature small pieces might drop off and choke the passage. Zinc protectors only act within limited distances, and require to be often renewed. It may also happen that small pieces are detached, and damage valves, &c.

Other experiments intended to find a substitute for copper to be used for condenser tubes and bolts, &c., were made, and copper bronze (97 per cent. copper, 3 per cent. tin), Duhre bronze, and a great number of other copper alloys have been tried. The English Admiralty, in the beginning of the eighth decade of last century, tried to stop quick corrosion of bronze condenser tubes by specifying condenser frames and tubes to be made out of the same mixture, the one being cast and the other drawn. The prevalent idea was that the cause of the destruction must be attributed to electrolysis set up by the use of different metals.

The destructive action of sea water on copper is, however, in the first place, a chemical process, as can be proved by exposing alloys of copper with tin or zinc and other metals in

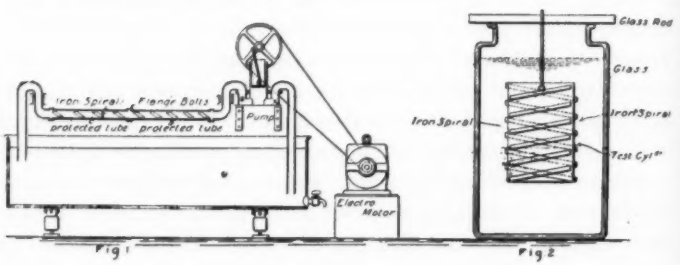
heated and condensed sea water where they will dissolve. Shortly after immersing the metal in sea water the latter becomes intensely blue, and the metal rod continually loses in weight, and, as can be seen from the annexed table, the loss is often very considerable. Rolled material with a high proportion of zinc does not dissolve so quickly, but in this case also the liquid shows quite distinctly some bright thread-like separations. The manufacture of a copper alloy which would stand casting, rolling and drawing equally well is a very difficult problem, but, even if solved, it would not produce condenser tubes incorrodible in sea water.

The tinning of tubes, as it is now carried out, offers a certain protection, provided the inside tinning is faultless and free from cracks; but this process, again, has the disadvantage of making the tubes very soft, owing to the tin bath forming an alloy with the tube material, no matter whether the latter is copper, bronze or brass. The temperature of the tin bath must be kept low by an addition of lead, otherwise the material will lose weight. The tin covering does not last longer than a year, and when renewed a certain percentage of the tubes is spoilt.

Some years ago sea-water pipes of copper and iron were lined inside with a layer of lead, which is impervious to sea water. Such layers cannot well be made of less thickness than 3 mm., consequently the tubes, on account of this lead layer, are heavy, and can only be bent slightly. Lead-lined tubes, therefore, are less suited to meet the difficulties than cast-steel tubes. The trials of ship plates by Davy, mentioned above, and the general experience that condenser tubes of brass and copper are little attacked in cast-iron condensers, suggested the expediency of making a trial to see if it were possible to counteract the chemical action of sea water by strong electrolytic action. As the latter can only be exercised within limited distances, it was thought advisable to spread the protector, in the form of a spiral, over the copper area, and to use a more solid and more electro-positive metal, such as iron, steel, &c., instead of zinc, which dissolves in water. In immersing a copper tube thus

prepared in sea water, a strong action producing bubbles and a yellowish coloring of the water sets in immediately. At first the iron is strongly oxidized, whereas the copper is not changed either in color or brightness. After some time the copper surface is covered between the coils of the spiral with a deposit of iron oxide, which soon adheres so firmly that it is able to withstand the action of flowing sea water. This layer of iron oxide, in fact, becomes so attached to the surface of the copper that, after the removal of the iron spiral, it cannot be wiped off with water, spirits or benzine. If it be removed by means of a scraper or some other sharp tool, the clean and untarnished copper surface appears under the brown layer of oxide of iron. Under the iron spiral itself the surface remains for some time almost unaltered, and the corrosion of the iron spiral is diminished as soon as the uncovered surface of the copper is covered with a lining of oxide. The protecting spirals consequently remain inactive for a long time, and even after their complete destruction the coating of oxide lining forms a protection for the copper against the dissolving action of the sea water. As a result of a great number of similar trials with copper either protected or otherwise with iron, in still or in flowing sea water, it has been ascertained that with iron protection the copper gains in weight, whereas without protection it continually lost weight. A trial with a copper tube lined with iron by the galvanic process showed that this covering dissolved in sea water. The surface of the copper became bare and was attacked. It was further proved that the iron protection not only remained intact with pure copper, but also with copper bronze. Brass and other tubes which consisted of segments of copper and brass respectively, which were soldered together, were tried. The condenser tubes when untinned, and when protected with iron, were found to last better than when tinned. The untinned material has the additional advantages that it is harder and resists better the expanding process of the ends into the tube plate. With iron protection it it not necessary to make the tubes from special copper bronze—97 per cent. Cu, 3 per cent. Z—as tubes made of ordi-

nary alloy, which are not half so expensive, can be equally well protected in the same way. The protection afforded by iron, however, is not confined to sea-water pipes only, but is also applicable to copper pipes fixed in the bilge. These ordinarily are corroded on the outside by the action of the bilge water, which is generally of an acid nature. In this case the iron spiral must, of course, be arranged on the outside. According to a preliminary trial, it seems even to be possible to protect copper coils used in the iron brine vessels of refrigerating plants by covering the former with wire. Trials have



been made in flowing and also in still water. Fig. 1 shows the arrangement used in the former. The tubes A and B undergoing the test were connected with a main through which sea water was pumped by an electrically-driven pump. The apparatus is at work for ten hours daily, and during the remainder of the time the water remains stationary in pipes and tank. The arrangements have been made as similar as possible to those which would be met with on board ship, the pipes being subjected to the joint influence of sea water and oxygen, which are favorable to the destruction of copper. The water is renewed from time to time, as a rule, once in two weeks, and the temperature in the trial room kept to about 20 degrees centigrade. The pumps are made of bronze. In front and behind the trial tubes A and B the main is bent a little upwards, so that there may always be some water in the pipes, which will thus be acted upon when the pumps are at a standstill. The trial tubes were made from copper, manufactured

both by the electrolytic and the ordinary melting processes. They were properly cleaned and polished inside and outside before use, then flanged, and each carefully weighed. The tests of the protected and non-protected tubes were carried out in similar apparatuses, under exactly similar conditions, and at the same time, consequently the behavior of both pipe lines could be compared directly. Different percentages of salt and other constituents were tried in the sea water, and differences were made in the bolts and flanges. To ascertain whether the protection was only local or was communicated to adjoining parts, the tube A only was protected with iron during one trial. At the conclusion of each trial the wire was removed, and the tube carefully cleaned with water, alcohol and benzine, afterwards being dried and weighed. Trials in still liquid

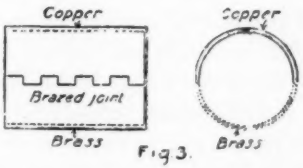


Fig 3.

were conducted with cylinders made of thin metal in glass vessels, as in Fig. 2. The cylinders were made of copper, produced by the melting process, also of copper bronze, brass and half copper and half brass, as per Fig. 3. These were polished before immersion, carefully cleaned and weighed. Condenser tubes of brass and copper bronze were also subjected to similar trials. The cylinders were tested when protected with iron partly inside only, and also when protected partly inside and outside. The temperature was fixed to 20 degrees centigrade, and the bath consisted of sea water from the Bay of Dantzig, which had been evaporated, so that it contained $3\frac{1}{2}$ per cent. of salt. Subsequently a solution of 3 per cent. of common salt was used, to which $\frac{1}{2}$ per cent. of magnesium chloride had been added. In another case $\frac{1}{10}$ per cent. of hydrochloric acid was added. This was done in order to ascertain whether the protection with iron would also be effective with acid bilge water,

which, it is notorious, attacks copper tubes vigorously. The trials extended over a period of two years, and the results are shown in the accompanying table. It was proved in all cases that with iron protection, not only copper, but its alloys gained also in weight, whereas without protection copper and its alloys, including those which are called impervious to sea water, suffer a continual decrease in weight.

Considering the great advantages which copper possesses for shipbuilding purposes as compared with all other metals, and that a substitute for it cannot be found, it is highly satisfactory, concluded Herr Uthemann, to have at last found the means to protect the same efficiently. "No doubt," he adds, "the use of copper in shipbuilding, which obviously has been restricted for some years, will soon grow to the right proportions."

It may be mentioned that at the beginning of the action there is a strong formation of rust on the iron protector, and it is advisable to rinse mains for washing and bathing purposes thoroughly before use, so as to get them clear of sea water. The formation of rust, however, only damages the steel wire a little, and in the tests the wire in the tubes had, in spite of its thickness of ½ mm., not lost its elasticity and cohesion after a year's work.—"The Engineer," London.

THE RELATION OF DEPTH OF WATER TO SPEED AND POWER OF SHIPS.

Some interesting data recently presented in "Engineering News" on the subject of change of draught and trim of vessels in motion, showed very clearly that the behavior of a moving ship depends on the depth of water under the keel. Those data suggested also that the power consumption of a vessel at given speed is affected by depth of water. Such a relation is of wider interest than the changes in draught or trim, but hitherto little has been available in the way of definite knowledge about the power relation. An experimental investigation of the subject made a year ago in the German Navy should therefore be interesting, the more so as the experiments were

made with a full-size vessel (as against model tests), and at such speeds that the reaction of the bottom upon the ship's resistance was felt through a very great depth of water. The investigation is reported in the "Zeitschrift des Vereines Deutscher Ingenieure" of December 10, 1904, by Naval Constructor Paulus, and the following summary is taken from that report.

Two trial trips of a certain torpedo vessel of the German Navy, made on two different measured-mile courses, but otherwise under practically identical conditions, gave speeds differing by about 1½ knots. The slower speed was obtained over the shallower course, having a depth of water of 60 to 80 feet, while the other course was in water nearly 200 feet deep. At first, going on the supposition that a depth of ten times the draught was sufficient to eliminate the influence of the bottom, the authorities were unable to understand this result. However, after a careful re-survey of the two courses, it was decided that no other source of difference existed, and experiments were ordered to investigate the question of influence of depth of water on speed.

The deeper of the two trial courses in question was found to be ideally located for the purpose of the experiments. A flat bottom of very gradual slope enabled all depths from 23 feet to 197 feet to be had in a series of parallel courses, with practical absence of currents. Six courses were laid out, in depths of water respecttively 7, 10, 15, 25, 40 and 60 m. (23, 33, 49, 82, 131 and 197 feet). The torpedo vessel *S119* was used for the experiments. The dimensions of this vessel are not stated. Brassey gives them as: Length, 207.7 feet; breadth, 22 feet; draught, 8.9 feet; displacement, 350 tons.

Six speeds were run, on consecutive days, over the group of six courses. The program for each day was as follows: Beginning with the deepest (197-foot) course, the vessel ran over this course, then turned and steamed back over the 131-foot course, then turned again and went over the 82-foot course, and so on until the 23-foot course had been run. Then it returned over the 23-foot course and worked back in similar

manner to the point of beginning. This entire double run was made at approximately the same speed, the steam valve being left untouched through the run except where necessary to maintain the speed reasonably uniform.

In a complete run as described, it will be seen that each course was covered twice, in opposite directions; the two results for each course were averaged to eliminate current and wind effects. The change in draught, from the beginning of double run until the vessel returned to the same point, was the only about 1¼ inches, which was almost negligible. Allowance for all differences in draught was made on the assumption that, for equal revolutions, speeds are inversely proportional to displacement, and hourly coal consumption directly proportional to displacement.

The measurements made during the runs were the following: Total revolution of engines; indicated power of all (6) cylinders; mean speed of vessel; trim of vessel, or longitudinal tilt compared with position at rest; shape of water surface along the side of the vessel. The trim was measured by two intercommunicating water gauges separated one-tenth of the vessel's length. The shape of water surface was measured from the deck by graduated rods at intervals of one-tenth the vessel's length.

The results are graphically summarized in the four diagrams, Figs. 1 to 4, herewith. They show (1) the variation of power with depth of water, for a number of different speeds; (2) the variation of power with speed, for six different depths, and in conjunction therewith the change in trim with increasing speed; (3) the variation in speed of revolution with speed of ship; and (4) the variation of slip of propeller with speed of ship. In all diagrams the speed range is the range between 12 to 27 knots, while the total available depth range, 7 m. to 60 m., is well covered by the six curves obtained. The indicated power is seen to vary from 300 H.P. to nearly 6,000 H.P.

The actual speeds used in the six runs were about 12, 15, 18, 21, 24 and 27 knots respectively. Many of the curves of

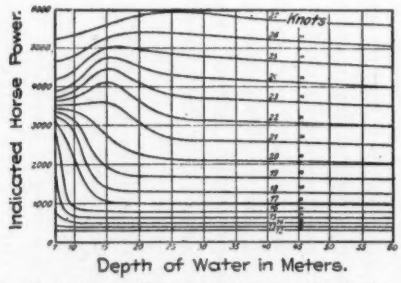


Fig. 1. Variation of Required Power with Depth of Water, for Various Speeds.

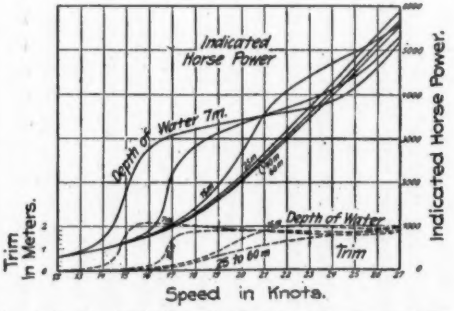


Fig. 2. Variation of Required Power and Trim of Vessel with Speed, for Various Depths of Water.

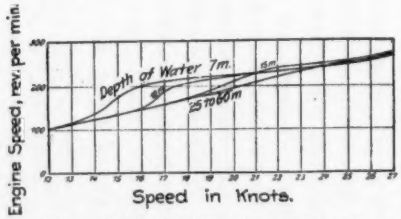


Fig. 3. Variation of Engine-Speed with Speed of Vessel, for Various Depths of Water.

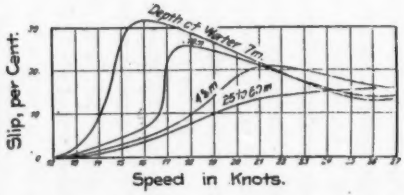


Fig. 4. Variation of Propeller Slip with Speed of Vessel, for Various Depths of Water.

Fig. 1 are therefore interpolated. In this diagram it will be noticed that curves of three kinds occur. At low speed, as 12 knots, the power is uninfluenced by depth of water (beyond 23 feet). At medium speed the power is very high in shallow water, decreasing rapidly up to 35 or 50 feet in depth, and then remaining fairly constant with increasing depth of water. At very high speed, however, the required power rises as the depth of water is increased from 23 feet, reaching a maximum, and then very gradually decreasing as the depth of water is further increased. The surprising result appears that at high speed the vessel consumed more power in water 200 feet deep than for the same speed in water only 23 feet deep, though at moderate speeds the shallow water consumes several times as much power as deep water.

In the horsepower speed diagram, Fig. 2, there are curves of two kinds, for deep and for shallow water, respectively, of which the former is the type. This deep-water curve rises from a value of about 300 H.P. for a speed of 12 knots, in roughly parabolic form, to a value of about 5,600 H.P. for 27 knots. For any depth, down to about 80 feet (25 m.) the curve is identical in form with this one, and lies only slightly above it. The 15-m. curve, however, shows a radical departure from this type. It begins at practically the same value for low speed, but at about 16 knots it rises suddenly and forms a pronounced hump, whose crest is in the neighborhood of 22 knots. Thence it rises much more gradually, and ultimately it crosses the deep-water curve, so that at very high speeds it calls for less power than the deep-water curve. The curves for depths of 10 m. and 7 m. show the same characteristics, but much more strongly, and at lower speeds in the shallower water. Thus, the 7-m. curve leaves the deep-water curve at a speed as low as 13 knots, reaches a crest at about 16½ knots, and again crosses the deep-water curve at 23 knots, showing lower values than any other curve for speeds beyond 23 knots. The enormous jump in required power as the speed is increased from 13 to 16 knots (500 horsepower to 2,800 horsepower) is especially striking.

The curves of trim in Fig. 2 correspond generally with the power curves. In deep water the stern sinks gradually and progressively, while in shallow water the stern sinks very suddenly at a point corresponding to the jump in the power curve. Similar characteristics appear in Figs. 3 and 4, showing engine speed and slip of propeller. However, these curves merely supplement, on the theoretical side, the power curves of Figs. 1 and 2.

It should be remarked that the tests here recorded covered six consecutive days, and were made in quiet water and under unusually favorable conditions. The results are, therefore, free from the influence of surface disturbance, as nearly as such tests can be.

The general effect of these experiments is to show that the influence of the bottom upon ships' motion extends through a far greater depth of water than had hitherto been supposed. Further, in such depths as allow of influence of bottom, say, less than 60 feet, there is a certain range of speed which is extremely wasteful of power, better results being obtained with lower and with higher speeds. Experiments upon vessels of other types and larger sizes than the one here used will be necessary to establish the results on a more general basis and to exhibit their dependence on size and shape of vessel. The close relation between required power and trim of vessel, apparent from Fig. 2, suggests clearly that the causes operating to produce change of trim are the same as those which increase the resistance of the vessel.—"Engineering News."

THE DEVELOPMENT OF THE TORPEDO-BOAT DESTROYER.*

In the case of the battleship, as compared with the destroyer, weight is of very much less moment, and it will be seen that the problem of how to give a maximum of strength with a minimum of weight, with a maximum speed with a minimum of coal consumption, must of necessity be the greater task in the destroyer.

* Abstract of a paper read before the Institute of Marine Engineers, by W. J. Harding, on March 13, 1905.

Torpedoes may be classed as fixed and moving. Of the fixed ones, our experience as a nation was gained during the Russian war of the fifties, when at least one of our ships was slightly injured in the Baltic by the explosion of a torpedo under her.

The moving torpedo, carried on the end of the spar, was used during the Civil War in North America, notably when Commander Cushing blew up the Confederate warship *Albemarle*.

After that we had the Harvey towing torpedo, which was an adaption of the canal barge towed from the bank, followed by the Whitehead invention, which has necessitated alterations and additions both of tactics and of shipbuilding.

The torpedo "drop gear," fitted to vedette boats, etc., was an adaption invented by Engineer Rear Admiral J. T. Corner, and is an arrangement of tongs which is lowered from the boat's side, submerges the torpedo, and, on tripping its regulating valve, thus setting the propeller in motion, releasing the tongs at the same time, the torpedo starts and soon finds its depth. These vedette boats of wood, sometimes called "torpedo boats, wood," in 1878 were 48 feet long and 12 knots speed, have been developed to 56 feet long. Special boats of this class, by J. Samuel White, of Cowes, have obtained 19 knots on trial.

In 1875 Messrs. Yarrow constructed a torpedo launch of the then high speed of 13 knots, fitted with a spar torpedo, and Sir John Thornycroft was the builder of the *Miranda*, in 1872. This vessel was 45 feet 6 inches long, and obtained a speed of 16.2 knots per hour. This firm constructed the first large torpedo boat for H. M. Navy. She was the *Lightning*, completed in 1877, her length 87 feet, speed 18½ knots, and she did many years of constant service at Portsmouth. Many torpedo boats for various governments were successively made by these leading firms.

The precursor of the destroyer class was evolved about 1884. Hitherto the plan had been to give torpedo boats an alternative armament, so that half of the boats might be employed

for firing torpedoes, the others acting as torpedo-boat destroyers, the boats armed by the small guns resisting attacks of torpedo boats. But as the speeds would be about the same in each, it is evident that neither could decrease the range of the other when attacking or escaping. Perhaps the first approach to the destroyer was the production of Messrs. John Samuel White, of Cowes. She was 150 feet long, fitted with twin screws and with more power—a larger vessel and better sea boat and of higher sea speed than those hitherto in use.

Messrs. Yarrow and Company constructed the *Kotaka* in 1885 for the Japanese Government. She was 170 feet long and fitted with twin screws, and practically an armored destroyer, being fitted with armor 1 inch thick round the machinery and boiler compartments sufficient to resist the fire from the torpedo boats.

About 1893 the "torpedo-boat destroyer" was evolved. Practically these destroyers were given just double the power of the latest torpedo boats in being. The hulls were built round them with due regard to the armament to be carried and the weight to be carried on trial, and also, of course, with due regard to the fact that they would be expected to be more seagoing. The draught was restricted to 5 feet, giving immunity from destruction by Whitehead torpedoes, which are erratic and inclined to "porpoising" if set to run at 5 feet depth or thereabout. They were armed with guns and Whiteheads, and so were calculated not only to destroy torpedo boats, but battleships.

Observers of the building of these hulls will note that a 5-pound plate—that is, $\frac{1}{8}$ inch thick—is a very limp object when received from the cogging mills, but after it has passed the leveling slab and been leveled it becomes very stiff; the leveling or "planishing" rendering the plate extremely stiff. The 27-knot destroyers were of various lengths, from 180 to 190 feet, and horsepower varying from 3,700 to 4,800.

One important improvement introduced by Mr. John Samuel White, of Cowes, prior to the year 1883, is a feature in all subsequent torpedo boats and all destroyers. This is the cutting

away of the "deadwood" at the stern, thereby securing a maneuvering power that would otherwise be scarcely possible, coupled with a more efficient feeding of the propellers so essential to high speed.

In the matter of speed the highest on the measured mile was given by the *Boxer*, by Thornycroft, the speed obtained being 29.1 knots with 4,490 H.P. In the matter of coal consumption the lowest was the *Hornet*, by Yarrow & Co. She burned 9,322 pounds per hour, giving 27.6 knots; the highest burning 17,122 pounds per hour, giving 27.4 knots.

As regards the boilers, it was proved that the locomotive boilers gave excellent results up to a certain grade of coal burning, and at slow burning they were very economical, but the tube ends could not be depended on to remain tight. These troubles were not experienced in water-tube boilers, which were of various systems.

Nevertheless, the locomotive boiler gave 1 H.P. for 1.33 square feet of heating surface, as against a maximum of 2.58 square feet in a water-tube boiler.

I think it may be said that the troubles of water-tube boilers arise primarily from faulty surface condensers, and had satisfactory surface condensers been in vogue when water-tube boilers were first adopted there is no doubt that much public discussion on the great water-tube boiler question would have been avoided.

Trials gave most valuable lessons in screw propellers. It had been customary in torpedo boats and prior boats that propellers should be of forged steel, and the substitution of manganese-bronze gave the then marvellous result of an increase of speed of about two knots an hour, this increase being obtained by using a manganese-bronze propeller of practically the same dimensions as those of forged steel, the figures being that at 384 revolutions per minute a forged-steel propeller gave 24¾ knots. The manganese-bronze one at the same revolutions gave 27 knots in the same vessel at the same draught.

Experiments showed that if only the indicated horsepower

were required, the propeller could be fitted which would give perhaps 20 per cent. more horsepower than an ordinary propeller. If the speed were required, a very different propeller would be adopted; but if speed coupled with a small coal bill were required, the propeller between these two would give the

DESTROYER, RIVER CLASS, CONTRACT SPEED, 25½ KNOTS.

Destroyer.	By whom built.	Speed obtained on full-speed trials.	Coal per I.H.P. on the high-speed consumption trial.	Air pressure on full-speed trial.
		Knots.	*Pounds*	*Inches.*
Welland	Yarrow & Co.	26.2	1.65	1.8
Usk	Yarrow & Co.	26.1	1.77	1.6
Teviot	Yarrow & Co.	25.9	2.07	2
Ribble	Yarrow & Co.	25.8	1.57	1.6
Exe	Palmer's Co.	25.6	2.11	2.4
Waveney	Hawthorn Leslie.	25.6	2.19	3.2
Derwent	Hawthorn Leslie.	25.7	2.24	2.8
Erne	Palmer's Co.	25.6	2.25	2.5
Dee	Palmer's Co.	25.5	2.28	2.6
Ettrick	Palmer's Co.	25.6	2.33	2.6
Cherwell	Palmer's Co.	25.6	2.34	2.7
Kennet	Thornycroft & Co	26	2.39	3.8
Jed	Thornycroft & Co.	25.7	2.46	4
Itchen	Laird Bros.	25.6	2.46	4.3
Blackwater	Laird Bros.	25.7	2.62	5.3
Arun	Laird Bros.	25.7	2.68	4.4
Foyle	Laird Bros.	25.6	2.79	4.4
Eden (turbine)	Hawthorn Leslie.	26.2	*	3.3

*Seven tons and nine hundredweight per hour.

LENGTHS, WEIGHTS AND SPEEDS.

Vessel.	Length.	Speed.	I.H.P. per ton of displacement.	Propellers.
	Feet.	*Knots.*		
Miranda	45½	16	14.7	Forged steel.
Torpedo boat	113	20	10.6	Forged steel.
Torpedo boat	115	21	10.6	Forged steel.
Torpedo boat	130	22	12.9	Forged steel.
Torpedo boat	140	23	15.6	Forged steel.
Torpedo boat	140	23	13	Manganese-bronze.
Torpedo boat	165½	25	15	Manganese-bronze.
River class	220	25½	12.6	Manganese-bronze.
Destroyer	185	27	15.7	Manganese-bronze.
Destroyer	215	30	20	Manganese-bronze.
Destroyer	228	31½	21.1	Manganese-bronze.

best results. Also that the proportions of the propeller influenced the coal per indicated horsepower, the coal per indicated horsepower propeller lacking in propulsive effect. The least immersion of the propellers gave the best results both in speed and coal bill; and the distance apart of twin-screw propellers was of moment.

I may give comparative instances of propellers showing how improvement was given: (*a*) Diameter increased 4 per cent., area increased 19 per cent., pitch not altered, the coal bill was decreased 27 per cent. at equal high speeds; (*b*) pitch fined 6 per cent., no other alterations, gave the same high speed with 10 per cent. less indicated horsepower and 17¾ per cent. less coal bill; (*c*) diameter increased 2 per cent., pitch fined 9 per cent., gave ¾ knot more speed, and coal bill decreased 40 per cent. at the same high speed obtained by the first propeller.

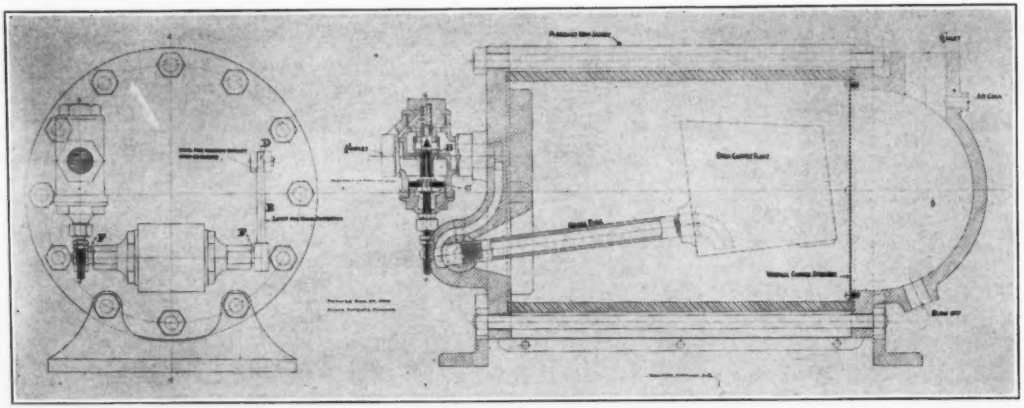
The terms of the trials for the 30-knot destroyers were very much amplified, for whereas in the former 27-knot destroyers there were no reserves of coal consumption, in these it was intended that 2½ pounds per indicated horsepower per hour should be a standard. This was much less than the average of the former 27-knot destroyers. Messrs. Thornycroft and Company obtained the first record for 30 knots in a British naval vessel at the Maplin Sands.

The 30-knot destroyers were followed by a reaction in favor of stronger vessels, now known as the "River" class. These vessels are of about 550 tons displacement, 200 to 230 feet long, and horsepower, 7,500.

The table from a Parliamentary return gives information of the "River" class. The table will show that in the 20-knot boats of the eighties it required 10½ H.P. per ton of displacement, and so on through each batch of vessels as they became larger.—"The Practical Engineer."

A NEW STEAM TRAP.

The steam trap, of which cut is here given, recently passed a successful test by a board of naval officers at the Norfolk



LYTTON STEAM TRAP.

Navy Yard. It was designed and built by Mr. J. W. Lytton, of Portsmouth, Virginia.

The trap has a cylindrical body of steel or wrought iron and two cast heads, the three parts being bound together with tie bolts, as shown in the cut. One of the heads holds the strainer, the dirt thrown off from which can be blown out through a drain connection. The other head contains the valve mechanism, which is arranged to be easily accessible. When, from accumulation of water in the body of the trap, the bucket becomes filled, it drops, and affords a passage for the water *via* the hollow bucket lever. The same motion trips the auxiliary valve A, which is seated on the main valve B. There results a flow of water down the hollow spindle of the main valve, and this water raises the main valve by acting on the under side of piston C. It is obvious that whenever the trap discharges it must be with a wide opening of the main valve. The auxiliary valve can be held in the open position by locking the arm E on trip shaft F with the pawl D.

The trap can be momentarily by-passed by tripping the auxiliary valve by light pressure on the arm E, the auxiliary valve being practically balanced under all steam pressures.

The trap can be easily and efficiently lagged, is of light weight for a given capacity, has free opening for discharge, may be easily overhauled, is not liable to serious derangement under ordinary conditions of service, may be readily by-passed, can be conveniently attached to a support, and can be manufactured at a low cost.

STEAM SUPERHEATERS—RECENT PROGRESS IN THEIR CONSTRUCTION.

By Maurice Miet.

(Reprint from the "Technical World," June, 1905.)

The principal results developed by the many experiments made during the past forty years in the use of superheated steam have been to bring out the exceedingly delicate character of the superheating apparatus that has been evolved, and to show the difficulty of properly maintaining it, the irregu-

larity of its action and frequently the ephemeral nature of its life.

So, in spite of the coal saving shown by superheaters, frequently amounting to as much as 20 per cent., the more delicate types have been abandoned. On the other hand, improvements made in recent years, especially by the substitution of cast steel for cast iron and by the elimination of concealed joints, have made it possible greatly to simplify and strengthen the construction. As a consequence of this the use of the superheater has become very extensive, especially in Germany, in connection with engines designed to use steam at temperatures of from 575 degrees to 675 degrees Fahrenheit; and it is thought that the same will soon be true in France, where superheaters had their birth and where they were first used.

GENERAL PRINCIPLES OF CONSTRUCTION.

The general principle followed in superheater construction has been to make them of a nest of tubes to be traversed by the steam, placed either in the fire box of the boiler itself or at some other point in the course of the hot gases; or away from the boiler altogether, where the superheater may be heated by its own fire. In either case the nest of tubes must satisfy the same conditions as far as circulation of the steam is concerned.

It is important to have a surface of sufficient extent to obtain the desired effect without involving the necessity of raising the tubes to too high a temperature regardless of the amount of steam flowing through them. Tubes uniting two collectors of different forms and arrangements ought to be of small diameter, so that the heating surface thus obtained shall occupy a small space, and the steam thus be kept in contact with the walls by which it is to be heated.

In order that the resistance to the passage of the steam may be reduced to a minimum, after having decided upon the diameter of the tubes, it is better that the headers used should be placed in parallel than in series, and that the several headers should be as short as possible. It is quite true that this arrange-

ment offers the disadvantage of multiplying the number of joints of these tubes upon their two headers; and, to use it, it will be necessary to have either an extra joint or a well-fitted thread.

The tubes of a superheater ought to be placed side by side, with sufficient space between them for the passage of the gases. For superheaters connected in any way with the fire box of a boiler, the volume of whose gases is always sufficient for the work, means should be adopted to regulate the heat of the nest by the use of a damper permitting a variation in the quantity of gases allowed to pass. In superheaters having an independent fire box it may be necessary to dilute the gases coming from the fire by an excess of air—which improves the combustion while lowering the temperature of the products of the same—so as not to expose the tubes of the first row to the dangers of burning. The natural result of this arrangement is that when these gases leave the superheater they still carry with them a considerable quantity of heat that it is well to utilize in an economizer.

In the above cases some sort of apparatus should be provided for the guidance of the fireman in the adjustment of the damper and the regulation of the fire. For this purpose, and for some years past, a thermometer has been placed in the steam at the point where it leaves the superheater. But the reading of this thermometer merely indicates the effects of the work of the fireman, and fails to indicate in advance what he ought to do, so that it acts rather as a controller than a guide. Furthermore, in case of a considerable diminution or an actual stoppage of the flow of steam, this thermometer placed really outside the superheater cannot indicate what is going on within, where the tubes may become red hot without so much as attracting the attention of the fireman. Such an arrangement of the thermometer is, therefore, insufficient, at least where the work can vary to any great extent and through periods of variable duration.

Better results have been obtained by the observation, not of the temperature of the steam, but of the hot gases at some con-

venient point in their course. In fact, by taking into consideration the fall in temperature of the gases in their passage over the nest of tubes of the superheater it can readily be ascertained whether the amount of heat given up by them is proportioned to the steam delivery—that is to say, whether the fireman is doing his work properly. In this it has been found that the temperature taken at any point whatever in the course of the gases should remain practically constant for different amounts of steam delivery.

Again, observations of practical workings show that, on account of the mass of masonry which surrounds the fire box, and which is an essential feature in the construction of a superheater, the temperature of the gases, as they reach the nest of tubes, changes very slowly in spite of any sudden opening of the doors for firing or other similar influences. At the same time, the temperature of the gases leaving the superheater is very even, or, at least it changes very slowly through rather narrow limits.

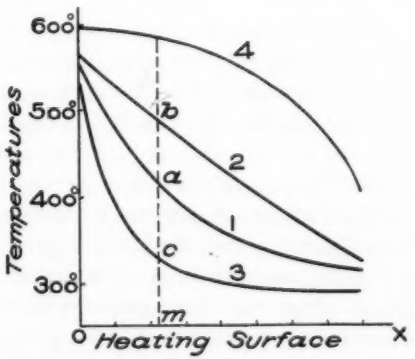


Fig. 1.—Curve Diagram of Temperature of Gases.

This does not hold true, however, in the space between the terminals; and, if we lay out the heating surface of the apparatus on the axis *OX* (Fig. 1), and indicate the corresponding temperature of the gases by the ordinates at each point, a curve like *1* will be obtained if the work of the superheater is good;

one like *2*, if the heat is excessive; and one like *3*, if it is insufficient. In fact, in the last case the first rows of tubes are quite able to absorb the greater part of the heat furnished them, while the back rows do not work at all. Finally, if the flow of steam is stopped, while the heat continues unchecked, a curve like *4* is obtained, wherein the gases are no longer cooled by the nest, but merely to a slight extent by the masonry.

This figure, obtained experimentally with a large superheater of recent construction, shows that at some point in the surface, such as *m*, there is a region in which the variation of temperature *mb* and *mc* is at a maximum; and that if a thermometer were to be located there in such a way as to maintain the indicated temperature near *ma*, it would forestall any variation of steam output, instead of following it. In fact, the steam temperature only follows the fire variations after some time has elapsed, the metal of the tubes forming a sort of calorific balance wheel, as it were.

LE CHATELIER PYROMETER.

The Le Chatelier pyromerer with a galvanometer attachment and a dial reading directly up to a temperature of 1,100 degrees Fahrenheit is the most convenient thermometer to use

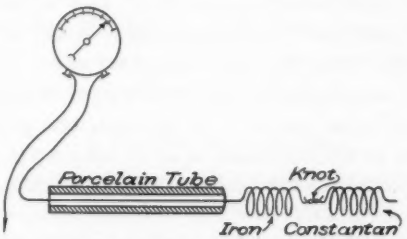


Fig. 2.—DIAGRAM OF LE CHATELIER PYROMETER.

for this purpose. This instrument (Fig. 2) makes it possible to observe the work of the tubes very easily, throughout the several sections of the apparatus, by admitting that the work of transmission of heat is proportional to the excess of tem-

perature of the gases above the metal at any particular point. This excess, in fact, is measured as follows:

A wire of iron and one of *constantan* (a special metal used in these pyrometers) are united with a twisted knot. The iron wire is passed through an insulating tube of earthenware or porcelain, and fastened to one of the terminals of a galvanometer of the proper sensitiveness, while a second iron wire leads from the other terminal to the piping of the superheater.

The end of the tube is then introduced into the chamber containing the nest of the superheater, and the wire of constantan brought into contact with one of the tubes, when a deflection of the galvanometer needle is obtained. The temperature of the knot is supposed to be the same as that of the medium in which it is placed, and the point of contact with the tube that of the tube itself, when the differential electromotive force which appears will be proportional to these two temperatures.

It would seem, then, that the use of an electric pyrometer, properly placed in the course of the fire-box gases, would serve to protect the tubes against being heated to redness, and thus preserve them from undue deterioration.

MODERN IMPROVEMENTS.

In the old superheaters a system of natural circulation was used, which possessed the disadvantage of exposing the tubes to overheating from the very hot gases when they were not being cooled, on account of the high temperature of these gases as they flowed over them. At present, comparatively fresh steam is used at the entrance, so as to take up the heat of the gases as they leave the fire box, and thus to protect the first rows of tubes.

Other practical details have also been subjected to important improvements, such as the means of removing and replacing the tubes, cleaning them, the construction of special piping for high temperatures, the jacketing, etc. These improvements, made in the construction of superheaters, have resulted in their use in service, where, besides the saving in fuel, they also effect

a great saving in the condensing and feed waters, besides permitting a reduction in the diameter and weight of piping and valves and avoiding all entrainment of water.

In the matter of the wear and lubrication of engines, oils are now available that will preserve their lubricating qualities at a temperature of 575 degrees Fahrenheit; while the dry lubricants—such as graphite, sulphur and talc—are available for higher temperatures, besides adding no oil to the water of condensation, and consequently none to the boiler feed.

The preceding principles have been applied all along the line by the builders of superheaters, with many interesting variations.

It is not the intention to enter upon an historical sketch of superheating, which would be for the most part a recital of the names of builders whose apparatus is no longer in existence, but to present those whose apparatus is today at work, and to whom the development of the present industry is due.

It may be well, however, to mention the apparatus of Becker (1827); Trewithik (1828); Raffard (1848); De Quillac (1849); Moncheul (1850); and, above all, Hirn (1855), whose work demonstrated beyond all peradventure that superheating does effect an actual and important saving.

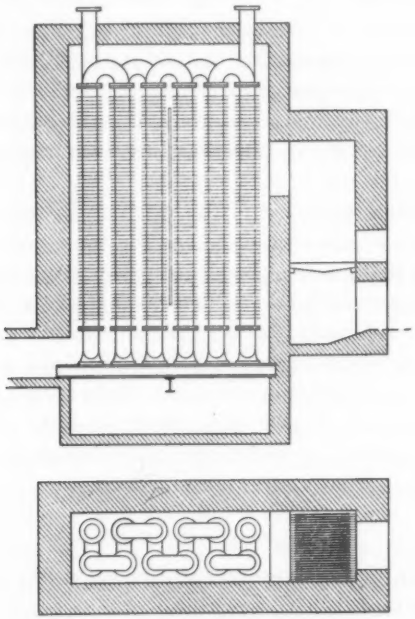
UHLER SUPERHEATER.

The Uhler superheater, recently brought out in Germany, is of an old model, with gas tubes in a cast-iron box, which has given way to numerous improvements.

SCHWŒRER SUPERHEATER.

Before speaking of the multitubular superheaters in use, attention should be called to the Schwœrer apparatus shown in Figs. 3 and 4, which has been extensively used with very few failures. This design is directly derived from that of Hirn. It is formed of a series of cast-iron tubes traversed by the current of steam and provided with a double row of inner ribs like those of the Serve tube, but less pronounced; while on the outside there are transverse ribs like those of a radiator. The

builder has thus secured an amount of heating surface within a given space, which, while not up to that of the most recent superheaters, is, nevertheless, a great advance over that of Hirn. Such an apparatus, when made of hard cast iron, will carry a pressure of 170 pounds per square inch.



Figs. 3 and 4.
VERTICAL SECTION AND PLAN OF SCHWŒRER SUPERHEATER.

GEHRE SUPERHEATER.

The Gehre superheater is formed of one or more cylinders, whose flat ends are perforated with holes, and stayed by a nest of tubes like a locomotive boiler. The fire-box gases pass through these tubes, and the steam circulates around them. The loss of weight which the steam experiences in this apparatus is insignificant, while it does require a decided increase of draft.

DECK SUPERHEATER.

The Deck superheater resembles the Schwœrer apparatus, except that the external ribs on the tubes are longitudinal, thus increasing the passage for the gases, and slightly decreasing the bulk of the whole.

RECENT GERMAN DESIGNS.

During recent years a great deal of work has been done by German designers, among whom the more prominent are Schmidt, Walther, Gohring, Steinmüller, Petry-Dereux, Durr, Buttner, Rodberg, Schwartzkoff, Hering, Guillaume and Wolf. It will be quite impossible, within the limits of this article, to describe the apparatus of all of them, so that attention will be limited to two—namely, Schmidt and Hering, whose devices have been extensively used in Germany and Austria, as well as to some extent in France.

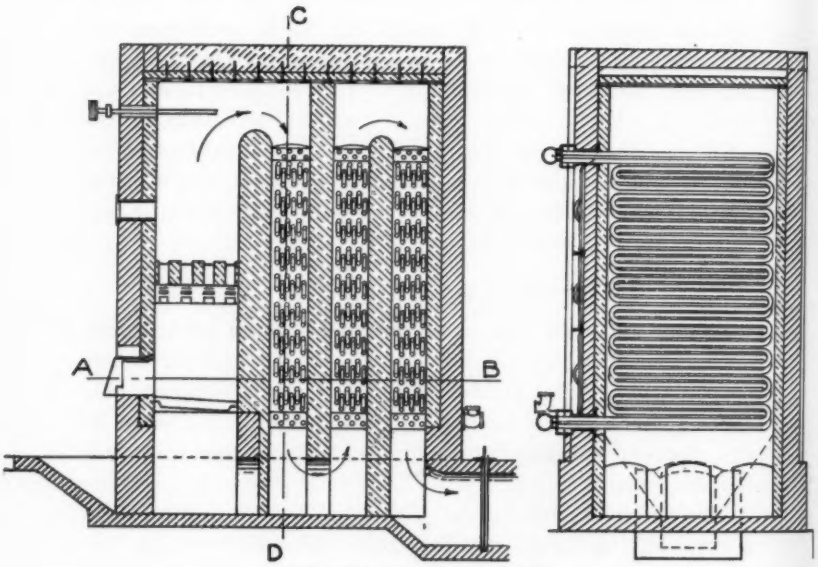
THE SCHMIDT APPARATUS.

Schmidt was the first who attempted to raise his temperature above 475 degrees Fahrenheit, which had previously been considered the highest limit of practical working. He conceived the idea of raising the temperature of the steam to 675 degrees Fahrenheit, a point at which good oils still remain intact.

The Schmidt superheater (Figs. 5, 6 and 7) is the first of a type having long, parallel, bent tubes, connecting two parallel headers. With this device the superheating improves as the flow of steam increases, for whatever is lost in pressure is gained in temperature. In order to avoid the disadvantages of a fixed circulation and relieve the first rows of tubes exposed to the hot gases, Herr Schmidt divides his nest of tubes into two parts traversed successively by the steam, and thus sets up two distinct nests with four cast-iron headers. The first nest is traversed by the steam in the same direction as the fire-box gases, and so as to take the damp steam, as it comes from the boiler, into the tubes subjected to the direct heat from the fire box. On leaving the first nest the steam passes

through the second in the regular way. This method has all of the advantages of the regular circulation, throughout the whole of the superheater, if, on leaving the first nest of tubes, the steam has merely been dried and not superheated at all.

Herr Schmidt has designed some arrangements for both boilers and engines intended for the production and use of superheated steam at and above 575 degrees Fahrenheit. He



SCHMIDT SUPERHEATER.

Fig. 5.—LONGITUDINAL SECTION ON E F. **Fig. 6.**—CROSS SECTION ON C D.

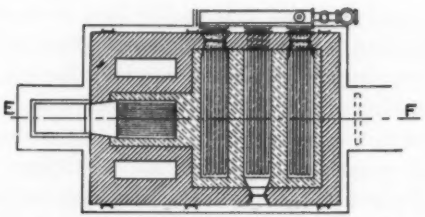


Fig. 7.—HORIZONTAL SECTION ON A B.

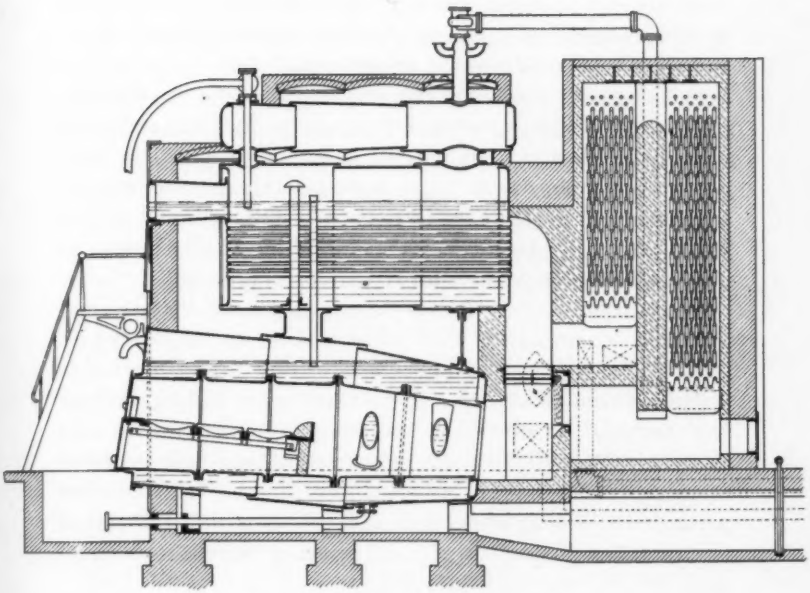


Fig. 8.—Longitudinal Section.

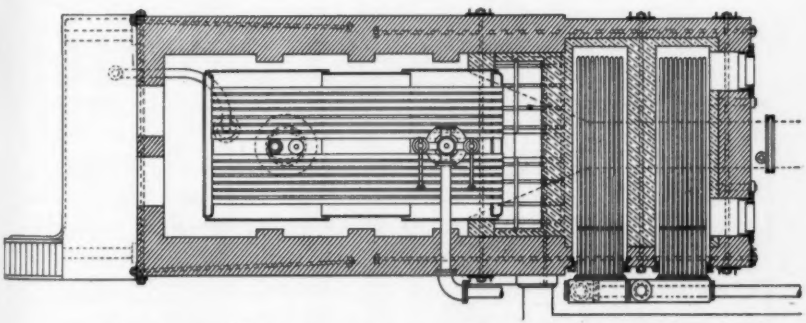


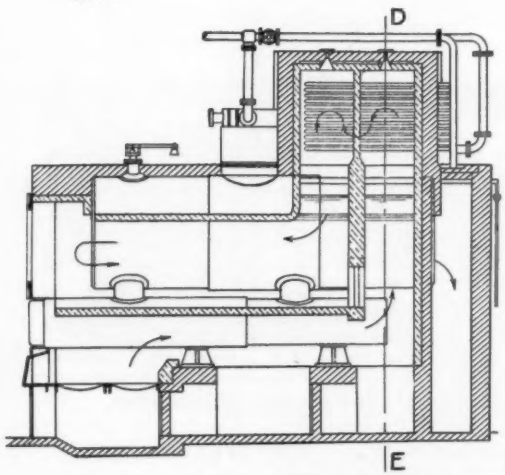
Fig. 9.—Plan.—Boiler fitted with Schmidt Superheater.

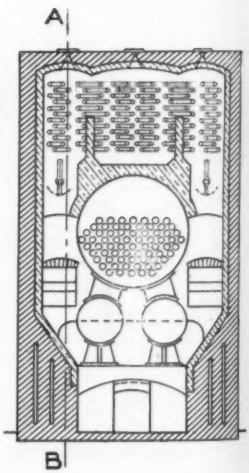
was probably the first to realize that in order to produce superheated steam advantageously, it was well to reduce the boiler in the neighborhood of the fire box (Figs. 8 and 9), and thereby

avoid the development of a heating surface each square foot of which becomes less and less efficient according as it is more and more removed from the bridge wall.

It is certainly a rational move to do away with the less efficient portions of the heating surface, and to replace them either with a superheater to which the gases are delivered at temperatures of from 925 to 1,475 degrees Fahrenheit, or with an economizer into which the feed water is pumped, and which, being cold and placed near the outlet, absorbs heat that it would be quite impossible for the boiler to take up.

The Schmidt boilers deliver superheated steam directly, and are built on principles that other makers are beginning to copy. These special arrangements make it possible to apply the Schmidt superheater to locomotive boilers without any essential modification and without interfering in any way with the draft. In the case of stationary boilers of the same class, but having larger tubes, another arrangement permits the placing of the U-shaped tubes forming the nest of the fire tubes themselves without injuring the steam production.





HERING SUPERHEATER.

Fig. 10.—LONGITUDINAL SECTION ON A B. **Fig. 11.**—CROSS SECTION ON D E.

THE HERING APPARATUS.

The Hering superheater (Figs. 10 and 11) is formed of weldless tubes 164 feet long. These tubes are bent into parallel sinuosities, and enter headers at each end in a way to leave the joints perfectly accessible from the outside. An arrangement of dampers makes it possible to regulate the range of temperature within narrow limits. The circulation of the the gases is so controlled that a deposition of soot upon the tubes is avoided, and the number of the latter is such that the velocity of flow of the steam need not be more than 82 feet per second.

MOST RECENT TYPES.

In most recent years the types of practicable superheaters have not been numerous, in spite of the veritable deluge of inventors who have appeared since the Paris Exposition of 1900, and the systems presented have little of interest. Hence only these devices will be cited which have received a practical application, to the exclusion of those subjected merely to laboratory experiment.

First, there is in the old Uhler apparatus, recently revived and remodeled, in which is embodied the original principle of the Field tubes, set up in chambers having a double bottom, but using steel instead of cast iron for the box, and with a conical thread for a fastening. The box is extended out to the masonry by two tubes for the admission and outlet of the steam, with joints that are not accessible (Figs. 12, 13 and 14). The return Field tubes leading to the lower box are no longer subjected to a possible clogging by the scale which may have been entrained, and which would have a tendency to accumulate at the bottom and cause them to burn out. The external cleaning of the tubes is made easy by removal of the false pieces. The circulation of the gases is maintained in such a way that the saturated steam on its entrance serves at the same time to protect the tubes from the direct action of the flames, and to absorb the heat of the gases as they leave, in the regular way. This arrangement lends itself to the use of high pressures and high temperatures. It produces a smaller loss

of steam pressure than other multitubular superheaters, with the same amount of heating surface.

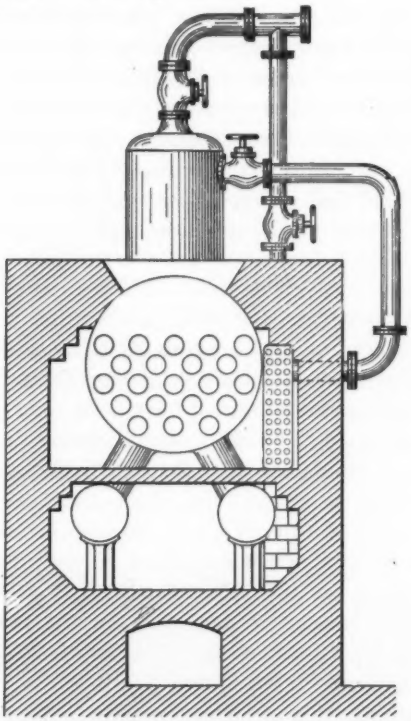


Fig. 12.—UHLER SUPERHEATER WITH HORIZONTAL TUBES.

In the Badere superheater, in order to avoid the complication of the double box or caisson, as in the Uhler apparatus, the Field tubes are not used, but U tubes whose two ends abut respectively into two compartments set side by side and into the bottom of which they are inserted. A common cover of the two forms a joint all around them.

M. Maiche uses tubes of iron or mild steel, as in other multitubular apparatus, but of a larger diameter. The originality of this apparatus consists in filling the interior of the tubes, where the steam passes, with a nest of thin tubes packed closely

against each other, whose object is to take the place of inner ribs on the Serve tubes forming the heating surface.

At first sight it would seem illogical to provide these tubes with ribs upon the inside only, and not upon the outside; but it should be noted that, under these conditions, the metal approaches more nearly the temperature of the steam than that

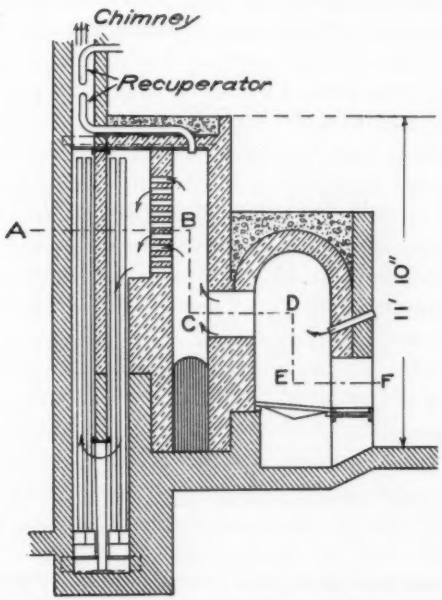


Fig. 13.—VERTICAL SECTION ON M N.
UHLER SUPERHEATER WITH INDEPENDENT FIRE BOX.

of the fire-box gases. The consequence is that the tubes thus protected are better able to support high-temperature gases, which is an advantage from the standpoint of the preservation of the material and economy of operation by permitting a reduction in the quantity of free air admitted above the grate. The installations of this apparatus in practical operation are not old enough or numerous enough to permit of judgment being passed upon the real value of the results that have been obtained.

The firm of Piat & Co., of Paris, have recently undertaken the construction of a new German superheater known as the "Schmidt Eindhoven."

A large number of the boilermakers have recently designed arrangements by which nests of superheaters can be attached to boilers. These arrangements, some of which are original, make, as a general thing, no pretense to the use of an independent fire box. The Roser apparatus may be cited as an example of this. It is formed of a thick block of cast iron, surrounding three sides of the fire box above the grate. Within the body of this wall are imbedded the iron pipes through

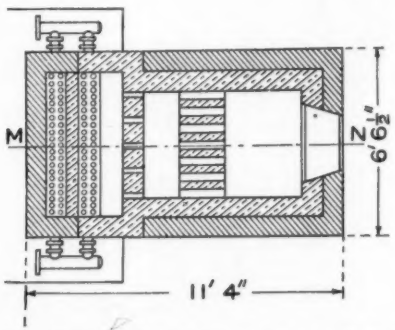


Fig. 14.—Horizontal Section on A B C D E F, Uhler Superheater with Independent Fire Box.

which the steam to be superheated is passed. As this arrangement admits of no regulation of the temperature of the steam, it can merely be admitted that the steam will be superheated to a temperature far above the point needed, so that it is mixed with a definite amount of saturated steam admitted through a special cock. This device is of comparatively recent origin, and has thus far received but a limited application.

This enumeration, although incomplete, shows that the problem of the construction of a practicable and durable superheater has been solved by a number of builders. Without speaking of those new ideas, of which some will undoubtedly be sanctioned by practice, there are several, such as the Uhler,

Schwœrer, Schmidt and Hering, which have already been put into extensive use, and have shown by a sufficiently prolonged service of ten years or more, that they are durable and reliable and good for many years to come. In Germany, where the most advanced work has been done, there are at the present time more than a thousand plants equipped for the use of superheated steam. And in France the large electric plants of Paris are being gradually fitted with superheaters.

H. M. SCOUT *FORWARD*.

Three of the eight scouts being built for the British Navy have now completed their trials, and in each case the guaranteed speed of 25 knots has been exceeded by quite a quarter of a mile per hour, notwithstanding onerous conditions as to the load to be carried on trial, &c., while the coal-consumption results indicate that the vessels have a greater radius of action than was anticipated. As the only element in their design criticised reasonably had reference to the distance they might travel with their full supply of fuel on board, the general issue is most satisfactory. The first vessel to pass through her trials was the *Sentinel*, built by Messrs. Vickers' Sons & Maxim, Limited. She is now in commission and doing well. The second was the *Pathfinder*, constructed by Messrs. Cammell, Laird & Co., Limited, Birkenhead, and the third, the *Forward*, was constructed by the Fairfield Shipbuilding and Engineering Company, Limited, Govan, Glasgow, and she attained a distinct success in her full-power run on Thursday, May 11th. Each of the firms named has another vessel nearly ready. The two others are being built by Sir W. G. Armstrong, Whitworth & Co., Limited, Elswick, the machinery being by Messrs. Hawthorn, Leslie & Co., Limited, Newcastle-on-Tyne.

For the present we confine ourselves to the *Forward* and her most satisfactory performance. In the course of the full-speed test of eight hours' duration she maintained a mean speed of 25.286 knots on six runs over the measured mile on the Clyde, while the engines were indicating 1,500 horsepower

less than the designed power. Running at 210 revolutions, 16,500 indicated horsepower was anticipated; on the measured-mile trial the mean revolutions were 211.8, and the power 14,995 indicated horsepower, the links on the twin engines being set to cut off at 58 and 57 per cent. of the stroke respectively. Some explanation for the higher ratio of speed to power than was aimed at in the design is found in the fact that the cruising speed was realized very economically as regards engine power and coal consumption, and that therefore a smaller load of fuel satisfied the condition of the contract, which required that the vessel should, on the full-power trial, carry coal to enable her to steam for 1,500 miles at 10 to 12 knots. The weights, too, evidently came out rather less than was anticipated, and thus the vessel met all the conditions for the full-speed trial on a displacement of 2,790 tons and a mean draught of 13 feet 10½ inches, instead of the estimated displacement of 2,850 tons on a draught of 14 feet 2 inches. But, apart from these facts, the speed and power results indicate a high Admiralty coefficient of fineness and a satisfactory efficiency in machinery and propellers. These latter, with three manganese-bronze blades, made detachable, have a diameter of 12 feet and a pitch of 14 feet 6 inches.

The *Forward* has a length between perpendiculars of 365 feet and a beam of 38 feet 9 inches. She has a considerable rise of floor from keel to bilge, approximating to the spinning-top section, and, in view of recent controversy, has full rather than hollow lines. The wave line was favorable to rapid steaming. She has a moderate freeboard, with a high forecastle and a half poop, of great advantage for sea steaming.

Another feature which distinguishes the *Forward* from some of the other scouts is that instead of having a protective deck she has 2-inch K.N.C. nickel-steel on the broadside from a depth of 2 feet 6 inches under the load line to the top of the side plating, and extending along the machinery and boiler compartments, which is equal to 127 feet of the length of the ship. The total depth of the plating is 11 feet 3 inches. Forward and aft there is a bulkhead of similar thickness, so that the boilers and engines are enclosed within a box with

2-inch nickel-steel walls. The bulkheads, dividing the boiler space into three compartments, have no openings; there is the usual door in the longitudinal dividing wall between the engine rooms. The ship is lightly armed, having ten 12-pounder and eight 3-pounder quick-firing guns, with two tubes on deck for firing Whitehead torpedoes. Although these vessels may successfully engage torpedo craft, the main function will be not to fight, but to scout in the danger zone and bring information. They lie low in the water, and their pole masts serve only for signaling and for wireless telegraphy.

The machinery, which is in duplicate for twin-screw propulsion, is of special interest, in that it may be said to occupy an intermediate position between those forms which have hitherto been associated with torpedo-boat destroyers and cruisers, respectively; thus the engines, although of the power of cruiser engines, are in general features of "destroyer" design, the cylinders being supported entirely on turned forged-steel columns. The bed plates are of somewhat novel design, and consist of a series of separate cast-steel transverse girders, each transverse girder being provided with one crank-shaft bearing. These cross girders or bearing frames are flat on the under side throughout their whole length, are six in number for each engine, and are connected at their ends by short distance pieces of cast steel. The engines, which are of the type known as four-cylinder, triple-expansion, are balanced on the Yarrow, Schlick and Tweedy system, with the low-pressure cylinders on the outside center line, and the low-pressure moving parts are of considerably lighter scantlings than those of the high and intermediate-pressure cylinders, as is the common practice with engines of this class. The valve gear is of the double-eccentric type, the quadrant links being of the double-bar type, and all joints are made adjustable. The slide valves for the high-pressure and intermediate cylinders are of piston form, and the low-pressure valves are of the flat type with relief rings.

The cylinders, which are all independent castings, and are not fitted with liners, are of the following diameters respectively: High pressure, 31½ inches; intermediate pressure, 50½ inches; and low pressure (of which there are two to each en-

gine), 57 inches; the stroke in all cases is 2 feet 6 inches. The pistons for the high-pressure and intermediate cylinders are of forged steel and the low-pressure pistons are of cast steel. The covers of all the cylinders are of cast steel. The shafting is hollow, the crank shafts being of 13½ inches external diameter and 6½ inches internal diameter, and the propeller shafts 14½ inches outside diameter, with an internal hole 5 inches in diameter.

The condensers are of rolled brass, built up and riveted together. One condenser is provided for each engine, and the total condensing surface for the ship is 14,022 square feet. Circulating water is supplied to these condensers by 17-inch centrifugal pumps. The air pumps are independently driven, of the twin direct-driven type, a double pump being provided for each set of engines.

Steam is supplied by twelve boilers of modified Thornycroft type, placed in three boiler compartments, and fired from six stokeholds. The aggregate tube surface is 42,960 square feet, and the total grate surface is 752.4 square feet. The working pressure is 260 pounds per square inch.

The conditions of contract required that the *Forward* should maintain for eight hours a speed of 25 knots while carrying in her bunkers sufficient coal to enable her to steam 1,500 nautical miles at from 10 to 12 knots; the amount was to be arrived at by taking the rate of coal consumption on a 96-hours' test. The exact speed to be made on this long trial was left to the discretion of the contractors, who chose the most economical rate. The *Forward* averaged throughout the 96 hours, as shown in Table I, a mean of 10.436 knots, and the mean power was 839 indicated horsepower, with the twin engines cutting off at 44 and 43 per cent. of the stroke respectively, and making 80.32 and 80.53 revolutions. On each morning of this 96-hours' trial the vessel returned to the measured mile at Skelmorlie to make six runs; the average speed on these was found to be 10.666 knots for 829 indicated horsepower realized for 82.2 and 82.9 revolutions respectively by the twin engines. The steam results are as follows:

Table I.—RESULTS OF 96 HOURS' COAL-CONSUMPTION TRIAL OF H. M. S. *FORWARD*, ON MARCH 28, 29, 30 AND 31, 1905, AT 10.436 KNOTS SPEED.

	Starboard.	Port.
Mean steam in boilers, pounds	142	142
at engines (high-pressure receiver), pounds	49.8	44.8
Mean air pressure in stokeholds	nil.	nil
cut off in high-pressure cylinder, per cent	44	43
vacuum, inches	24	24.8
revolutions per minute	80.32	80.53
pressure in cylinders, high, pounds	17.1	15.2
intermediate, pounds	5.7	4.68
low, forward, pounds	1.87	2.64
aft, pounds	1.76	2.69
Indicated horsepower, high	162	146
intermediate	139	113
low, forward	58	82
aft	55	84
Total indicated horsepower	414	425
Gross total indicated horsepower	839	
Coal per indicated horsepower per hour, pounds	2.661	
Water loss per 1,000 indicated horsepower per 24 hours, tons	4.13	
Mean indicated horsepower on miles	829	
Speed, mean of six runs on course, knots	10.666	
96 hours, knots	10.436	

The coal consumption worked out at 2.661 pounds per indicated horsepower per hour, or, as near as may be, to 1 ton per hour. At this cruising speed, therefore, the vessel steams 10½ miles per ton of coal. The vessels have capacity for carrying 500 tons of coal, so that the high economy realized will enable 5,000 miles to be run at 10½ miles, which is much greater than was anticipated when the order for the ships was placed. As the *Forward* has realized her full speed for a low power, her radius of action at 25 knots will be correspondingly increased, and thus she will be the more serviceable in war times. On the full-speed trial the supply to enable her to go 1,500 miles at 10½ knots speed was exactly 145¼ tons. This was the load carried when she commenced her eight-hours' trial on the 11th instant. The displacement was then 2,790 tons, the draught forward being 13 feet, and aft 14 feet 9 inches, giving a mean of 13 feet 10½ inches. The vessel was required to make six runs over the measured mile within one hour and a half of the commencement of the eight-hours' trial, and the results are as follows:

SIX RUNS ON THE MEASURED MILE AT FULL SPEED.

Run.	Revolutions.	Speed, knots.	Indicated horse-power.
1	213.5	25.568	15,121
2	213.5	25.245	15,301
3	212.5	25.532	14,970
4	211	25.07	14,806
5	210	25.21	14,498
6	213	25.281	15,277
Mean	211.8	25.286	14,995

These results were attained with the engines cutting off at 58 per cent. and 57 per cent. of the stroke respectively. The boilers were steaming easily, the air pressure in the stokehold being 1½ inches, as shown in the first column of Table II, which sets out the mean results from the machinery during these six runs. The second column of the table gives the results for the subsequent 6½ hours of the test.

Table II.—RESULTS OF FULL-POWER EIGHT-HOURS' TRIAL OF H. M. S. *FORWARD*, MAY 11, 1905.

	Mean of six runs on measured mile.		Mean of subsequent 6½ hours of trial.	
	Starboard.	*Port.*	*Starboard.*	*Port.*
Mean steam in boilers, pounds	250		250	
Mean steam at engines (high-pressure receiver), pounds	227	234	227	234
Mean air-pressure in stokeholds, inches	1.5	1.5	1.8	1.8
Mean cut-off in high-pressure cylinder, per cent	58	57	59	59
Mean vacuum, inches	25.3	24.8	25.2	24.8
Mean revolutions per minute	211.6	212	211.7	209.8
Mean pressure in cylinders:				
High, pounds	109	111.3	112.1	112.3
Intermediate, pounds	34.5	31.9	34	35.3
Low, forward, pounds	14.83	16	15.1	15.8
aft, pounds	14.85	15.3	15	15.54
Indicated horsepower, high	2,727	2,792	2,803	2,782
intermediate	2,224	2,248	2,186	2,247
low, forward	1,217	1,313	1,235	1,282
aft	1,218	1,256	1,226	1,261
Total indicated horsepower	7,386	7,609	7,450	7,572
Gross total indicated horsepower	14,995		15,022	
Total water loss for all 8 hours, tons	13.6			
Speed, knots	25.286			
Loss of water per 1,000 I.H.P. per 24 hours, tons	2.71			

It will be noted that the engines in the subsequent 6½ hours of the trial averaged over 210 revolutions, so that the speed was well over 25 knots. The machinery worked satisfactorily, while the engine room was more comfortable than is usual with high-speed machinery. From first to last the performance was most favorable. After the trial various other tests as to the maneuvering capabilities of the ship were carried out, and the vessel returned on the 12th instant to Fairfield, to be completed for commission, which will take about two months. The sister ship—the *Foresight*—will leave the same works shortly for speed trials.—London "Engineering," May 19, 1905.

STEAM TESTS OF COAL.

Extract from the preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo.

METHODS OF CONDUCTING TESTS.

The method of testing fuels under boilers has been a subject of discussion for many years by the members of the American Society of Mechanical Engineers, and as the result of this discussion a standard method of conducting tests and of reporting the results has received the approval of this society. The steam tests of coal at the Geological Survey testing plant have been conducted and the results reported in accordance with these methods and forms.

The number of tests made was seventy-eight. The duration of each was planned for ten hours, and was as near this time as the conditions at the close of a test would permit. An experienced and careful fireman hand-fired all of the coals tested.

DESCRIPTION OF THE BOILERS.

There were two 210-horsepower Heine safety boilers provided for these tests. They were exactly similar in construction and setting. Each was provided with its own stack, 115 feet high and 37 inches in diameter. Each boiler was fed by its own

independent injector, and no other means of supplying water to the boilers was provided. The ends of the blow-off pipes were visible during all tests.

In the next table the leading proportions of one of the boilers are given.

The boilers were cleaned externally after each test. The interior condition of each boiler was practically clean during all of the tests.

LEADING PROPORTIONS OF HEINE WATER-TUBE BOILERS USED IN COAL-TESTING PLANT.

Rated capacity of boiler, horsepower	210
Water-heating surface, square feet	2,031
Superheating surface	None.
Grate area, square feet	40.6
Kind of draft	Natural.
Height of steel stack, feet	115
Area of steel stack, square feet	7.67
Number of tubes	116
Outside diameter of tubes, inches	3.5
Steam pressure, pounds	85
Observations taken every 20 minutes.	
Approximate duration of each trial, hours	10

DESCRIPTION OF THE STEAM ENGINE AND GENERATOR.

The steam generated by the boilers was largely used by an Allis-Corliss engine of 250-horsepower capacity, and the power of the engine was absorbed by a 200-kilowatt direct-current, 240-volt Bullock generator, to which the engine was belted.

The engine was the simple noncondensing type. The cylinder was 22 inches in diameter and the stroke was 42 inches. The engine ran about 80 revolutions per minute.

Numerous tests made to determine the steam consumption of the engine, as well as the mechanical efficiency of the engine and generator together, gave the following average results:

AVERAGE RESULTS OF ENGINE AND GENERATOR TESTS.

Number of pounds of steam used per hour per indicated horsepower developed by the engine	23.60
Mechanical efficiency of the engine and generator combined (per cent.)	81

From these figures has been calculated the electrical horse-power delivered to the switchboard for such tests of the boilers as were not accompanied by a test of the engine and generator.

COALS TESTED.

The coals tested are arranged alphabetically according to the States from which they were obtained. Some of these coals were washed and some were briquetted. In all tests of coals other than slack, the coal was first passed through rolls having an opening of 1½ inches, which crushed it to uniform size. On pages 515 to 517 is a table which gives some of the results of the tests, and in which the character of the coal used in each boiler trial is clearly indicated.

LIST OF COALS TESTED.

Alabama No. 1. First test: Lump and nut coal from mine No. 8 of the Ivy Coal and Iron Company, Horse Creek, Ala.

Second test: Large briquettes containing 7 per cent. of pitch binder.

Alabama No. 2. Lump, nut and pea coal from mine No. 5 of the Galloway Coal Company, Carbon Hill, Ala.

Arkansas No. 1. First test: Lump and nut coal from mine No. 3 of the Central Coal and Coke Company, Huntington, Ark.

Second test: Large briquettes containing 9¼ per cent. of pitch binder.

Arkansas No. 2. First test: Lump coal from mine No. 12 of the Central Coal and Coke Company, Bonanza, Ark.

Second test: Large briquettes containing 11 per cent. of pitch binder.

Arkansas No. 3. First test: Lump and slack coal from mine No. 18 of the Western Coal and Mining Company, Jenny Lind, Ark.

Second test: Large briquettes containing 8.7 per cent. of pitch binder.

Arkansas No. 4. First test: Large briquettes made from slack coal from several Arkansas mines, furnished by the Western Coal and Mining Company, St. Louis, Mo. Briquettes contained 6 per cent. of pitch binder.

Second test: Small briquettes made with patent binder.

Arkansas No. 5. Lump and slack coal from mine No. 4 of the Western Coal and Mining Company, Coal Hill, Ark.

Colorado No. 1. Run of mine black lignite, from Simpson mine, of the Northern Coal and Coke Company, Lafayette, Colo.

Illinois No. 1. Lump and nut coal from mine No. 1 of the Western Anthracite Coal and Coke Company, near O'Fallon, Ill.

Illinois No. 2. Washed slack coal, from same as Illinois No. 1.

Illinois No. 3. Run-of-mine coal from mine No. 3 of the Southern Illinois Coal Mining and Washing Company, near Marion, Ill.

Illinois No. 4. First test: Lump coal from mine No. 3 of the Donk Brothers Coal and Coke Company, Troy, Ill.

Second test: Same as above.

Illinois No. 6. Run-of-mine coal from shaft No. 1 of Clover Leaf Coal Company, Coffeen, Ill.

Indiana No. 1. Washed run-of-mine coal from Mildred mine of the J. Woolley Coal Company, Mildred, Ind.

Second test: Large briquettes made from washed coal, containing 7 per cent. of pitch binder.

Indiana No. 2. Run-of-mine coal from Electric mine of the T. D. Scales Coal Company, Boonville, Ind.

Indian Territory No. 1. Lump and slack coal from mine No. 1 of the Whitehead Coal and Mining Company, Henryetta, Ind. T.

Indian Territory No. 2. Run-of-mine coal from mine No. 8 of the Rock Island Coal Company, Hartshorne, Ind. T.

Indian Territory No. 3. Run-of-mine coal from mine No. 1 of D. Edwards & Son, Edwards, Ind. T.

Indian Territory No. 4. Lump coal from mine No. 5 of the Western Coal and Mining Company, Lehigh, Ind. T.

Iowa No. 1. Lump and fine coal from mine No. 2 of the Anchor Coal Company, Laddsdale, Iowa.

Iowa No. 2. Run-of-mine coal from mine No. 6 of the Mammoth Vein Coal Company, near Hamilton, Iowa.

Iowa No. 3. Lump coal from mine No. 4 of the Gibson Coal Mining Company, Altoona, Iowa.

Iowa No. 4. First test: Lump coal from mine No. 3 of the Centerville Block Coal Company, Centerville, Iowa.

Second test: Large briquettes containing 8 per cent. of pitch.

Iowa No. 5. Run-of-mine coal from Inland mine No. 1 of the Inland Fuel Company, Chariton, Iowa.

Kansas No. 1. Run-of-mine coal from mine No. 10 of the Western Coal and Mining Company, Fleming, Kans.

Kansas No. 2. First test: Lump and nut coal from mine No. 11 of the Western Coal and Mining Company, Yale, Kans.

Second test: Same as above, except washed.

Kansas No. 3. First test: Run-of-mine coal from mine No. 9 of the Southern Coal and Mercantile Company, Scammon, Kans.

Second test: Same as above.

Kansas No. 4. Lump coal from mine of the Atchison Coal Mining Company, near Atchison, Kans.

Kansas No. 5. Lump and nut coal from mine No. 11 of the Southwestern Development Company, West Mineral, Kans.

Kentucky No. 1. Run-of-mine coal from Straight Creek mine No. 2 of the National Coal and Iron Company, Straight Creek, Ky.

Kentucky No. 2. First test: Lump, nut, pea and slack coal from mine No. 11 of the St. Bernard Mining Company, Earlington, Ky.

Second test: Large briquettes containing 8 per cent. of pitch.

Kentucky No. 3. Run-of-mine coal from Barnsley mine of the St. Bernard Mining Company, near Earlington, Ky.

Kentucky No. 4. Run-of-mine coal from mine of the Wheatcroft Coal and Mining Company, Wheatcroft, Ky.

Missouri No. 1. First test: Run-of-mine coal from New Home mine No. 1 of the New Home Coal Company, located at Sprague, Mo.

Second test: Large briquettes containing 11½ per cent. of pitch.

Third test: Same as test No. 1.

Missouri No. 2. First test: Run-of-mine coal from mine No. 8 of the Northwestern Coal and Mining Company, Bevier, Mo.

Second test: Same as above.

Missouri No. 3. First test: Slack coal from mine of the Mendota Coal and Mining Company, Mendota, Mo.

Second test: Same as above, except washed.

Missouri No. 4. Run-of-mine coal from mine of Morgan County Coal Company, near Barnett, Mo.

New Mexico No. 1. Lump and slack coal from Weaver mine of the American Fuel Company, three miles north of Gallup, N. Mex.

New Mexico No. 2. First test: Slack coal from Otero mine of the Caledonian Coal Company, two miles east of Gallup, N. Mex.

Second test: Small briquettes containing patent binder.

North Dakota No. 1. Run-of-mine brown lignite from Lehigh, N. Dak.

Pennsylvania No. 1. Coal from Eureka mine No. 31 of Berwind-White Coal Mining Company, Windber, Pa.

Pennsylvania No. 2. Coal from Eureka mine No. 31 of Berwind-White Coal Mining Company, Windber, Pa.

Pennsylvania No. 3. Small briquettes made with patent binder from anthracite culm furnished by Pennsylvania Coal Company, Scranton, Pa.

West Virginia No. 1. Run-of-mine coal from mine of the Virginia and Pittsburg Coal Company, Kingmont, W. Va.

West Virginia No. 2. Run-of-mine coal from Pitcairn mine of the Pitcairn Coal Company, Clarksburg, W. Va.

West Virginia No. 3. Run-of-mine coal from mine of West Virginia Coal Company, Richard, W. Va.

West Virginia No. 4. Run-of-mine coal from mine of the West Virginia Coal Company, Bretz, W. Va.

West Virginia No. 5. Lump and nut coal from mine of the Davis Colliery Company, Coalton, W. Va.

RESULTS OF COAL TESTS UNDER BOILERS.

Test No.	Name of sample.	Coal, size and condition.	Chemical composition.					Duration of trial.	Total coal consumed.	Horsepower developed by boiler.	Dry coal burned per square foot of grate surface per hour.	Equivalent evaporation from and at 212 degrees Fahr. per pound of dry coal.	Dry coal per indicated horsepower hour.	Dry coal per electrical horsepower hour.
			Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur (separately determined).							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Hours.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*
17	Alabama No. 1	Nut, bright	52.52	31.00	2.56	13.92	0.78	10.03	8,656	205.8	20.72	8.44	3.35	4 14
21	do	Large briquettes	50.96	33.00	2.63	13.41	.94	8 25	6,521	196.6	18.97	8.81	3.21	3.96
16	Alabama No. 2	Mine run, bright	48.65	32.98	4.83	13.54	1.17	10.02	9,198	216.4	21.54	8.55	3.31	4.08
9	Arkansas No. 1	Lump, bright	66.36	18.61	1.99	13.04	1.21	10 07	7,071	180.5	16.90	9 05	3.12	3.86
14	do	Large briquettes	67.65	21.21	.94	10.20	1.73	10.03	7,700	206.4	18.74	9 37	3.02	3 73
8	Arkansas No. 2	Lump, bright	73.65	16.86	1.07	8.42	1.95	10.07	6,517	180.6	15.70	9.73	2.91	3.59
11	do	Large briquettes	60.30	22 49	4.88	12.33	1.32	9.98	7,370	190.3	17.31	9 31	3 00	3.71
29	Arkansas No. 3	Mine run, bright	72.74	16.04	1.97	9.25	1 29	10.02	8,158	219.7	19.68	9 50	2.98	3.68
35	do	Large briquettes	62.04	17.35	2.60	18.01	1.41	10.08	8,600	200 8	20.49	8.34	3.39	4.19
40	Arkansas No. 4	do	71.98	14.06	3.85	10.11	1.64	9.95	8,142	214.5	19 41	9 40	3.01	3.72
42	do	Small briquettes	66.03	18.60	3.18	12.19	1.70	7.03	5,238	166.8	17.78	7.98	3.54	4 38
41	Arkansas No. 5	Nut, bright	73.68	12.54	2 22	11.56	2.39	10 13	9,000	202.4	21.42	8 04	3.52	4.34
75	Colorado No. 1, lignite	do	39.00	35.85	19.78	5.37	.42	9 97	8,972	151.0	17.80	7.21	3.92	4.85
18	Illinois No. 1	Nut, dull	38.21	36 91	9.69	15.19	4.40	9.93	11,124	211.4	24.90	7.21	3.92	4.85
19	Illinois No. 2	Slack, dull, washed	41.72	37.77	10.45	10.06	3.36	9.97	10,096	210.2	22.36	8.00	3.54	4.38
38	Illinois No. 3	Nut, dull	48.75	31.19	8.51	11.55	1.50	10.13	9,537	200.6	21.23	8.04	3.52	4.34
48	Illinois No. 4	Lump, dull	41.59	33.48	13.47	11.46	1.28	10.07	9,367	172.0	19.84	7.37	3.83	4.73
50	do	Nut, dull	43.63	32.44	12.58	11.35	1.36	10.02	10,750	197.8	23.13	7 27	3.89	4.80
73	Illinois No. 6	do	39 62	32.31	13.19	14.88	3 48	9.92	10,343	194.3	22.34	7.40	3.82	4.72
71	Indiana No. 1	Large briquettes	43.23	38.79	11.74	6.24	2.03	6.60	6,579	222.6	21.70	8.73	3.24	4.00
68	do	Nut, dull, washed	40.41	35.17	16.59	7 83	2.18	9.93	10,819	222.7	22.39	8.45	3.34	4.13
65	Indiana No. 2	Nut, dull	40.40	38 04	9.11	12.45	4.12	10.13	9,274	193.4	20.51	8.02	3.53	4.35
10	Indian Territory No. 1	Mine run, bright	46 30	33 96	7.65	12.09	1.80	9.75	8,210	194.7	19.17	8.64	3.27	4.04
20	Indian Territory No. 2	Nut, bright	50.31	36.21	3.71	9.77	1.39	10.17	9,213	212.9	21.50	8.42	3.36	4.15
32	Indian Territory No. 3	do	47 58	37.30	4.79	10.33	3.93	10.02	9,145	205.9	21.43	8.17	3.46	4.27

NOTES.

RESULTS OF COAL TESTS UNDER BOILERS.—Continued.

Test No.	Name of sample.	Coal, size and condition.	Chemical composition.					Duration of trial.	Total coal consumed.	Horsepower developed by boiler.	Dry coal burned per square foot of grate surface per hour.	Equivalent evaporation from and at 212 degrees Fahr. per pound of dry coal.	Dry coal per indicated horsepower hour.	Dry coal per electrical horsepower hour.
			Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur (separately determined).							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Hours.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
52	Indian Territory No. 4	Nut, bright	45.33	35.44	6.24	12.99	3.86	10 22	9,296	186.1	21.04	7.53	3.76	4.64
45	Iowa No. 1	Nut, dull	39.89	33.08	8 69	18.34	6 39	10.02	10,331	197.7	23.23	7.24	3 91	4.82
67	Iowa No. 2	Nut, very dirty	33.73	35.35	14 88	16.04	4.73	9.92	10,986	192.7	23.28	7.05	4.01	4 95
49	Iowa No. 3	Nut, dull	35.77	36.14	12.44	15.65	6.07	10.03	10,668	189.3	22.96	7.02	4.03	4.97
47	Iowa No. 4	Mine run, dull	37 28	34 09	13 48	15.15	5.04	10.00	9,385	167.3	20.02	7.11	3.98	4.91
66	....do....	Large briquettes	37 85	36.50	13.24	12 41	3.90	10.03	9,900	184.5	21.11	7.43	3.80	4.70
55	Iowa No 5	Nut, medium bright	38.83	31.76	16 01	13.40	3.09	9.98	11,200	204.7	23.23	7.50	3.77	4 66
6	Kansas No. 1	Lump, dull	49.46	33.78	5.90	10.86	3.82	10.10	7,222	158 2	16.60	8.11	3.49	4.31
7	....do....	Mine run, dull	48.57	32.68	4.80	13 95	4.94	9 70	7,492	184.0	18.13	8.63	3.28	4.05
5	Kansas No. 2	....do....	46.68	31.23	4 18	17.91	6.27	7.00	5,600	181.5	18.90	8.17	3.46	4.28
13	....do....	Nut, dull, washed	51.22	34.32	5.82	8.64	3.77	9.38	8,111	209 8	20.08	8.89	3.18	3.93
3	Kansas No. 3	Mine run, dull	50.99	33.52	2 03	13.46	5.39	9.91	7,700	169.6	18.77	7.69	3.68	4.55
4	....do....	....do....	51.05	34 30	2.25	12.40	4 80	10 40	7,101	148.8	16.45	7.69	3.68	4.55
58	Kansas No. 4	Nut, bright	43.59	36.32	5.51	14.58	8.46	10.05	7,835	165.5	18.18	7.75	3.65	4.51
72	Kansas No. 5	....do....	51.36	32.42	4.31	11.91	4.40	9 90	8,651	215.2	20.62	8.88	3.18	3.93
60	Kentucky No. 1	Nut, very clean	55.59	35.61	2.89	5.91	1.19	10.03	8,355	212.3	19.95	9.06	3.12	3.86
57	Kentucky No. 2	Nut, bright	45.75	37.91	7.76	8.58	3.37	10.00	9,557	208.5	21.75	8.16	3.47	4.28
76	....do....	Large briquettes	44.32	37.07	7 11	11.50	3.71	9.82	9,371	207.1	21.87	8.06	3.51	4.33
64	Kentucky No. 3	Nut, bright	44.84	37.32	7.92	9.92	3.91	10.07	9,645	211.5	21.75	8.27	3.42	4.22
62	Kentucky No. 4	....do....	45 74	35.65	5.89	12 72	3 72	9.93	9,386	211.7	21.90	8.21	3.44	4.25
12	Missouri No. 1	Mine run, dull	40.64	34.88	7.28	17.20	4.37	10.00	9,737	207.4	22.30	7.92	3.57	4.41
23	....do....	Large briquettes	41.85	37.60	6.38	14.17	4.56	5.10	4,500	191.2	20.37	7.99	3.54	4.37
15	....do....	Nut, dull, washed	44.21	36.81	7.93	11.05	3.58	9.91	9,041	207.0	20 71	8.50	3.33	4.11
37	Missouri No. 2	Nut, dull	37.33	32.88	13.09	16.70	4.92	9 98	11,650	208.2	25.00	7.08	3.99	4.93
44	....do....	....do....	39 76	31.77	11.57	16.90	4 60	9 98	9,248	172.5	20.20	7.26	3.90	4.81
78	Missouri No. 3	Nut, dull	29.98	26.18	18.63	25.21	3.85	9.95	10,828	149 5	21.85	5.82	4.86	6.00

78	Missouri No. 3	Nut, dull	29.98	26.18	18.63	25.21	3.85	9.95	10,828	149 5	21.85	5.82	4.86	6.00
77	....do	Nut, dull, washed	39.61	31.18	20.78	8.43	2.88	9.93	11,044	189.7	21.72	7.43	3.81	4.70
70	Missouri No. 4	Nut, dull	42.11	40.10	12.24	5.55	4.58	9.98	9.515	214.1	20.64	8.83	3.20	3.96
27	New Mexico No. 1	Mine run, clean	41.57	37.85	11 90	8.68	.56	10.05	10,963	206 3	23.70	7.41	3.96	4.90
26	New Mexico No. 2	Pea, dull	36.11	37.30	9.92	16.67	1.13	10.00	11,870	198.5	26.37	6.41	4.41	5.45
30	....do	Small briquettes	39.07	37.56	6.75	16.62	1.61	8.12	7,765	185.8	22.00	7 19	3.93	4.86
33	North Dak. No. 1, lignite	Nut, brown	25 40	28.13	35.84	10.63	1.68	9.85	10,680	108.9	17.15	5.40	5.24	6.47
1	Pennsylvania No. 1	Mine run, bright	75.69	15.80	1.10	7.41	1.49	9.88	6,365	166.9	15.70	9.04	3.11	3.84
2	Pennsylvania No 2	....do	76.76	16.61	.59	6.04	.91	10.08	6,835	191.2	16.60	9.79	2.89	3.57
36	Pennsylvania No. 3	Small briquettes	55.00	27.62	3.00	14.38	1.13	10.08	8,012	184.5	19.01	8.26	3.42	4.23
24	West Virginia No. 1	Nut, bright	56.25	34.64	1.90	7.21	.98	9.98	7,818	199.2	18.94	8.95	3.16	3.90
25	West Virginia No. 2	Mine run, bright	48.80	39.23	2.01	9.96	2.71	10.22	8,354	212.4	19.75	9.14	3.09	3.82
28	West Virginia No. 3	Nut, bright	56.11	30.31	2.54	11.04	1.38	9.97	8,225	211.6	19.82	9 08	3 11	3.84
31	West Virginia No. 4	....do	59.84	27.64	2.53	9.99	.96	10.00	7,895	215.1	18.98	9.65	2.93	3.62
34	West Virginia No. 5	....do	58.66	28.95	2.11	10 28	1.01	10.08	7,700	207.8	18.44	9.59	2.95	3.81
39	West Virginia No. 6	....do	70.03	22.38	2.14	5.45	.70	9.95	7,406	213.2	17.95	10.09	2.80	3.46
43	....do	....do	71.42	21.44	2.11	5.03	.64	10.18	7,264	208.5	17.21	10.30	2.74	3.39
51	West Virginia No. 7	....do	68.27	20.23	2.68	8.82	1.52	10.18	7,700	210.1	18.15	9.85	2.87	3.55
53	West Virginia No. 8	....do	56.68	31.19	5.26	6.87	.74	9.98	7,997	211.6	18.72	9.62	2.94	3.63
69	West Virginia No 9	....do	59.47	31.11	3.42	6.00	.82	10.00	7,464	210.8	17.78	10.09	2.80	3.46
54	West Virginia No. 10	.... do	73.84	18.23	1.74	6.19	.59	9.93	7,441	205.9	18.15	9.65	2.93	3.62
56	West Virginia No. 11	....do	68.36	16.31	4.85	10.48	.47	9.97	7,700	213.7	18.13	10.03	2.82	3.48
46	West Virginia No. 12	....do	75.33	18.26	1.58	4.83	.59	10.13	7,399	206.1	17.68	9.90	2.86	3.53
59	....do	Small briquettes	67.46	24.02	2.32	6.20	.84	10.25	7,515	211.8	17.66	10.20	2.77	3.42
63	Wyoming No. 1	Nut, bright	31.61	40.56	21.81	6.02	.63	10.15	11,946	186.6	22.69	7.00	4.04	4.99
61	Wooming No. 2	Nut, very dirty	34 58	35.55	11.10	18.77	3.87	9.95	12,028	184.3	26.51	5.92	4.77	5.90

West Virginia No. 6. First test: Run-of-mine coal from mine of the New River Smokeless Coal Company, Rushrun, W. Va.

Second test: Same as above.

West Virginia No. 7. Run-of-mine coal from mine of the New River Smokeless Coal Company, Sun, W. Va.

West Virginia No. 8. Run-of-mine coal from mine of the Gauley Mountain Coal Company, Ansted, W. Va.

West Virginia No. 9. Run-of-mine coal from Vulcan mine of the Mount Carbon Coal Company, Limited, Powellton, W. Va.

West Virginia No. 10. Lump and run-of-mine coal from Stuart M. Buck, Mora, W. Va.

West Virginia No. 11. Run-of-mine coal from mines Nos. 1 and 2 from W. H. Coffman, Zenith, Va.

West Virginia No. 12. First test: Run-of-mine coal from mine of the Big Sandy Coal and Coke Company, Big Sandy, W. Va.

Second test: Small briquettes made with patent binder.

Wyoming No. 1. Black lignite from mine of the Wyoming Coal and Mining Company, Monarch, Wyo.

Wyoming No. 2. Run-of-mine coal from Antelope Nos. 1 and 2 and Jumbo mines of the Cambria Fuel Company, Cambria, Wyo.

RESULTS OF THE COAL TESTS UNDER THE BOILERS.

The accompanying table shows some of the most important practical results of the tests of coals burned under the boilers. In each test an effort was made to operate the boiler at a point very near its rated capacity. In some cases the coals tested presented difficulties which made it impossible to accomplish this result. The various coals were tested in the order of the "test numbers" given in column 1, and tests of coals from widely separated localities were frequently made on successive days.

Attention is called to "rate of combustion" at which the coals were burned. To those familiar with tests of this char-

acter it will be evident that the coals were for the most part burned at a rate calculated to give approximately the most favorable results.

All of the chemical results reported in this table were furnished by the chemical laboratory in charge of Prof. N. W. Lord, which is sufficient guarantee of the accuracy.

The "horsepower developed by the boiler," recorded in column 11, refers to the standard boiler horsepower and is the evaporation of 34.5 pounds of water per hour from a feed-water temperature of 212 degrees Fahrenheit and at atmospheric pressure.

In column 13 will be found recorded the number of pounds of water evaporated by one pound of dry coal at and from a temperature of 212 degrees Fahrenheit. This column gives the best comparative results of the relative values of the coals tested, as far as these results relate to their commercial values.

The final report on these tests will give the values of all the items of the standard code report of the American Society of Mechanical Engineers and the complete logs of all tests, as well as a graphic chart of each trial.

PRACTICAL DATA ON EUROPEAN PRACTICE WITH STEAM TURBINES.

The remarkable development of the steam turbine in this country in connection with power plants makes it of interest to discuss European practice, which has covered a period beginning, perhaps, ten years before active work was started here. The lowest steam consumption under actual working conditions in Europe is 9.11 pounds per indicated horsepower hour, although this does not include the power required to operate the condenser outfit, which in this country is usually considered not over 5 per cent. The lowest record for reciprocating engines is 9.41 pounds (including condensers), which is attained both at one of the street-railway power plants in Berlin and in Vienna.

Although there are some half-dozen different types of turbine

in use on the continent, the Brown-Boveri-Parsons is the most popular, being installed in some 150 plants throughout Europe.

The rapid increase in the use of the turbine during the past five years was due very largely to the successful operation of the municipal plant in Elberfeld, Germany, for running the suspended railway between Elberfeld and Barmen. Here they have two 1,000-kw. Parsons turbines, which operated, even at the early date of their installation, with a minimum steam consumption of 12.3 pounds per indicated horsepower per hour for one, and 12.1 pounds for the other.

The steam turbine, like the reciprocating engine, may be run both condensing and with free exhaust, and the jet condenser, the surface condenser, the siphon condenser or a central condensation system may be employed. As there is no oil used in the steam chambers of the turbine, the water from the condenser may be used directly for boiler feed or for other purposes, and it is not necessary to filter it and thus lose a large portion of its heat. The absence of oil in the condensed steam is of special advantage when surface condensers are used, as in this case the cooling water does not mingle with the condensed steam, and the feed water returned to the boilers is thus always pure and free from sediment. It is for this reason that surface condensers are specially appropriate for turbine plants. Quite contrary to the practice in this country, most of the condensers and pumps in these plants in Europe are driven by electric motors.

A turbine lends itself much more readily to the advantageous use of superheated steam than a reciprocating engine, on account of the absence of pistons, stuffing boxes and cylinder lubrication. As the economy due to superheated steam increases directly with the temperature, the turbine presents another advantage, because there is practically no limit to the superheat it can stand.

The steam consumption of the Parsons turbine, used on the continent, as already shown, will compare favorably with that of the best compound engine built today. The accompanying table gives some data regarding the steam consumption of

Parsons turbines furnished by Brown, Boveri & Co., of Baden, Switzerland, and installed in a number of different plants. All the turbines are run condensing, and the steam consumption given in the table includes that required for the auxiliaries, except those cases marked*, where this work is not included. The table shows clearly the decrease in steam consumption as the size of the turbine and degree of superheat increase, and from the data here given it may safely be expected that in the 10,000-H.P. turbine, which is at present being constructed by Brown, Boveri & Co., that the steam consumption will be considerably less than 9 pounds per indicated horsepower per hour.

In comparing the results of the turbine tests with those of reciprocating engines it must be borne in mind that it is usual to make special preparations before testing reciprocating engines, while there being no parts of the turbine subject to excessive wear, there is no necessity for special preparation at the time of test; indeed, tests made several years apart will show the same results.

TABLE SHOWING PERFORMANCES OF BROWN-BOVERI-PARSONS TURBINES, DIRECT-CONNECTED TO C. E. L. BROWN ELECTRIC GENERATORS.

Location of plant.	Output.	Output.	Steam pressure, absolute.	Temperature, steam.	Steam per I.H.P. hour.
	kw.	*H.P.*	*pounds.*	° *F.*	*pounds.*
Refrigerating plant, Berlin*	100	133	129	372	15.6
Electric plant, Chur	200	267	184	482	13.6
French navy yard*	280	420	216	†	13.8
Nord-Deutcher Lloyd, Bremen	300	400	147	†	14.
Steam railway, Linz, Switzerland	300	400	132	†	14.3
Cellulose factory, Villach	350	467	169	482	12.1
Rolling mill, Antonienhütte*	400	533	110	†	13.
Ship yard, Kiel*	400	533	132	†	13.
Spinning mill, Colmar*	400	533	162	445	11.7
Mine and pottery, Tschopeln	400	533	110	406	13.
Iron and steel works, Diedenhofen	450	600	118	482	11.8
Iron and steel works, Hösch*	500	667	110	452	12.5
Schlieper & Baum, Elberfeld	500	667	147	482	11 6
Municipal plant, Frankfort*	3,000	4,000	162	572	9.11

* Steam for power to operate condenser not included. † Saturated.

As an example of the stability and slight wear of the turbine, it may be interesting to refer to the 500-H.P. Brown-Boveri-Parsons turbine in the Carlshuette at Diedenhofen, Germany, which was in service 5,800 hours continuously, except for a single stop of ten minutes' duration. At the end of the run the turbine was taken apart by the company's engineers and examined carefully for evidence of wear, of which not the slightest could be found.

In comparing performances of reciprocating engines with those of turbines, it is necessary not only to take into consideration the steam consumption of the engine and turbine, but also to consider the wear and tear on the engine and the oil required.

The Bavarian Inspection Society thoroughly investigated this subject of oil, and found that in compound and triplex expansion engines of 100 to 1,500 H.P. the oil consumption was about 2 grammes per horsepower hour, costing 1/40 cent. In the Parsons turbine the oil consumption is practically negligible as compared with reciprocating engines, the figures being 0.1 to 0.3 gramme per horsepower hour in units of 100 to 1,500 H.P. With the reciprocating engine the cost of the oil consumed amounts to 7 to 15 per cent. of the cost of the coal used, while with the Parsons turbine the cost of the oil ranges from ½ of 1 per cent. to 2 per cent. of the cost of the coal.

The attendant delay due to the preparation of an additional reciprocating unit for service is entirely avoided with the turbine, for it is equipped with a by-pass valve, by means of which steam at full pressure may be admitted to the second or low-pressure steam chamber, and the capacity of the turbine is thus largely increased. This by-pass is also a great advantage in case of an accident to the condensing apparatus which would necessarily decrease the power of the turbine, just as it would in the case of an engine. The use of this by-pass, however, means a less economical steam consumption.—Franz Koester, in "Engineering Record."

VARIATIONS IN ANGULAR VELOCITY OF SHAFTING.

The following notes, published in "London Engineering," are from a paper read by Mr. J. H. Heck, before the Institution of Naval Architects:

Mr. Heck had devised an instrument by which the angular velocity of the tunnel shaft could be graphically recorded during parts of a revolution. It consisted of a small electric motor, which was kept revolving at a high speed, current being supplied by a storage battery; this was mounted above the shaft to be operated upon. At the lower end of the spindle of the motor there was a brass sleeve, fitted eccentrically, carrying a pencil holder, so that when the spindle was revolved and a sheet of paper was held stationary underneath, small circles of $\frac{5}{16}$-inch in diameter would be traced. The motor was fixed to a small teak frame, which could slide easily along a teak batten or straight-edge about 6 feet to 7 feet long, fixed in the shaft tunnel in a fore-and-aft direction, the position being such that the center of the spindle of the motor was directly over the longitudinal center line of the shafting. The pencil was kept in contact with the paper by an elastic spring. It will be seen that a sheet of paper placed around the shafting would have traced on it by the pencil a loop-curve. When the engines were running at various speeds, the curves were obtained by bringing the pencil in contact with the paper and starting the motor, which, when in full motion, was pushed slowly along the batten by hand, the pencil thus describing what the author called a continuous screw-thread of loop curves which enveloped the shafting. The distance between each small curve from crest to crest represented the distance passed over by a point in the periphery of the shaft during a small uniform interval. By counting the number of loops, the number of revolutions of the motor for one revolution of the engine was determined, and by measuring the distance between the crests of the small curves or loops and dividing this distance by the radius of the shaft, the angle in radians passed through by the crank could be arrived at.

Some interesting results were obtained in this way. In a

cargo vessel fitted with two-crank compound engines, the propeller well immersed, on comparing one-eighth of a revolution with another one-eighth of the same revolution, the variation in the angular velocity of the shafting at 58 revolutions was 12 per cent.; making the same comparison between two quarter revolutions the variation was 8.6 per cent. With a small vessel with two-crank compound engines working at high pressure, the propeller immersed, one-eighth of a revolution compared with another one-eighth of the same revolution gave a variation in angular velocity of the shaft at 93 revolutions of 12 per cent., and at 60 revolutions 24 per cent. Making the same comparison with quarter revolutions at 93 revolutions, the variation was 9.8 per cent. A large cargo and passenger steamer, fitted with three-crank triple-expansion engines, working at 180 pounds pressure, propeller just immersed, gave, on comparing one-eighth of a revolution with another one-eighth of the same revolution, a variation in angular velocity at 66 revolutions of 4.6 per cent., and at 54 revolutions 5.5 per cent. This was a good result. Making the same comparison with quarter revolutions at 66 revolutions, the variation was 2.1 per cent. With a cargo steamer fitted with three-crank triple-expansion engines working at 180 pounds pressure, the tips of the propeller blades 20 inches out of the water, a comparison of one-eighth of a revolution with another one-eighth of the same revolution gave a variation of angular velocity of the shafting at 71 revolutions of 5.6 per cent., and at 61 revolutions 4.6 per cent. Making the same comparison with two quarters of a revolution, the variation at 71 revolutions was 2.15 per cent.

With a large cargo vessel, fitted with a four-crank quadruple-expansion engine, balanced on the Yarrow-Schlick-Tweedy system, working at 110 pounds pressure, tips of the propeller blades 55 inches out of the water, on comparing one-eighth of a revolution with another one-eighth of the same revolution the variation in the angular velocity of the shafting was, at 66 revolutions, 4.6 per cent.; at 48 revolutions, 4.4 per cent.; comparing two quarter revolutions at 66 revolutions the variation

was 1.2 per cent. In the case of a small high-speed passenger engine, fitted with a four-crank quadruple-expansion engine, balanced on the Yarrow-Schlick-Tweedy system, and working at 200 pounds pressure, the propeller being immersed 4 inches, it was found, on comparing one-eighth of a revolution with another one-eighth of the same revolution, that the variation of the angular velocity of the shafting at 104 revolutions was 4.9 per cent. and at 55 revolutions 5.5 per cent. This was also a good result.

As an illustration of the effect of slight racing on the variation of the angular velocity of shafting a case was taken of a large cargo and passenger steamer, a sister vessel to the one above named, fitted with three-crank triple-expansion engines. The propeller was fully immersed, the tips of the blades being 24 inches under water. The engine was racing at times, though not very much. When no racing was apparent, on comparing one-eighth of a revolution with another one-eighth of the same revolution, the average variation of velocity in the shafting at 68 revolutions was 7 per cent. to 9 per cent.; while when racing was evident, comparing one-eighteenth of a revolution with another one-eighteenth of the same revolution, the variation in velocity was 21 per cent.; or, in other words, while the average number of revolutions of the engine was 68 per minute, the engines actually during part of one revolution were going at the rate of 82 revolutions, while during another part of the revolution they were going at the rate of 58 revolutions per minute. It was to be judged from this that, if engines were racing heavily at sea, it would be found that the acceleration at intervals in the rate of revolution per minute would be considerable, and quite sufficient to account for the signs of straining which had appeared in the machinery of vessels that had encountered very bad weather. At low speeds of revolution the variation in the angular velocity per revolution was nearly always greatest, and as the revolutions increased in number the variations became less. When there was an exception to this rule vibration became apparent, and when vibration increased the variation in the angular velocity increased.

In the discussion which followed, Mr. Cole asked what precautions were taken to ensure uniformity of speed of motor.

Mr. R. E. Froude thought it was certainly an important question whether engines went round at a uniform speed. One interesting point that came out of this investigation referred to the slip of the propeller. Variation in the speed of revolution would naturally cause additional strains upon the propeller blades.

Mr. Heck, in replying to the discussion, said that the paper gave the bare results. The Germans had done much in investigations of this nature, and he was glad to follow their lead. The question was one which would have to engage the attention of engineers. The trials showed that when the variation in angular velocity of the shafting was least the consumption of coal was most favorable. Vessels in heavy weather must have an acceleration that was something enormous, and which had not been considered even by the best engineers. It was known how any movement, such as chattering, absorbed power in any machine. Another point that came forward was that the heavy engine gave less variation than a light one. The motor was so wired that the speed of rotation was constant. Nothing, of course, in this respect was perfect, but he thought they had arrived at conditions that were not far out. He had used more than one motor, and the results with different machines practically confirmed each other.

WATER-TUBE BOILER DESIGN.

Water-tube boilers may be broadly divided into two classes, according to the general position of the tubes. In one class the tubes run in a vertical, or nearly vertical position, while in the other the position is nearly horizontal. The respective merits of these two arrangements are discussed at length in a paper presented before the North-East Coast Institution of Shipbuilders by Mr. W. R. Cummins, and the general subject of the design of water-tube boilers is treated at length in the same connection.

Mr. Cummins naturally considers the boiler with especial reference to marine service, but the general points apply to stationary purposes as well. The conditions necessary for commercial success in a boiler are enumerated as those affecting the fuel economy, the weight and space economy, the cost or capital economy, and the economy of operation or maintenance. The relative importance of these various conditions depends somewhat upon the service, the matter of weight, for instance, being an important question for a marine boiler, and of secondary consideration for land service.

The conditions necessary for high fuel economy are stated to be perfect combustion and perfect efficiency of heating surface.

"Perfect combustion is an unmixed blessing and does not interfere with any of the other economical conditions. On the other hand, to secure perfect efficiency of the heating surface would mean an almost unlimited amount of it, which would seriously interfere with weight and cost of economy.

"One of the chief sources of loss in burning fuel in a boiler is due to the excess air which has to be admitted to provide for complete combustion to CO_2 and H_2O. The whole of this excess air has to be heated up to the temperature of the rest of the gases and thus carries off a great deal of heat to the funnel. This source of loss is common to all boilers and may be largely reduced by skilled firing and proper proportioning of firebar spaces and air admission. It is very probable that with oil fuel the excess of air over that actually required for perfect combustion is not so much as with coal fuel; hence the furnace efficiency should be greater."

In considering steam-boiler economy it must always be remembered that the furnace is distinctly a piece of chemical apparatus, and that its function is the production of heat by the combustion of fuel, while the boiler proper is a piece of physical apparatus, designed to absorb the heat produced in the furnace and convert it into mechanical energy in the steam.

Considering the furnace in itself, it is generally admitted

that the form and size of the combustion chamber is an important element. By the combustion chamber is meant the space immediately succeeding the grate, along the direction of the movement of the products before the actual heating surface of the boiler is reached. In order that the combustion should take place effectively it is necessary that the gases should be caused to mingle thoroughly with the air, and that sufficient time should be given for the chemical changes demanding a high temperature to be completed before the cooling surfaces of the boiler are reached. The rate of transfer of the heat from the gases to the water depends upon their difference in temperature, so that the efficiency of both the furnace and the boiler depend to a large degree upon the production and maintenance of a high temperature in the combustion chamber. In any case the time occupied by the passage of the gases through the boiler is never more than a few seconds, so that every facility for the completion of the combustion and the transfer of the heat must be given if even a fair degree of efficiency is to be secured.

Mr. Cummins points out that the various designs of boilers with vertical water tubes give an excellent opportunity for the provision of a large combustion space having its greatest dimension in the line of the flow of the gases, while those forms in which the tubes are horizontal, or nearly so, have the lower rows of tubes just over the grate bars, where the green gases coming off the fuel must be cooled down below combination temperature. In some forms of boilers the combustion takes place in a sort of Dutch oven, placed in front of the boiler proper, this being a recognition of the desirability of providing for better facilities for combustion before the heating and cooling surfaces of the boiler are reached.

Coming to the elements in design which affect the efficiency of the boiler itself, Mr. Cummins shows that the maximum possible economy in the transfer of the heat depends upon heating-surface efficiency. Theoretically the greatest efficiency would be obtained when the temperature of the escaping gases in the chimney was just equal to the tempera-

ture of the water in the boiler, but such a condition is commercially impracticable. In actual practice the attention which can be given to heating-surface efficiency is limited by other requirements, and, like all other engineering structures, a steam boiler is a compromise.

When economy in weight is the controlling question the heating surfaces are necessarily restricted, and the chimney temperatures are consequently high. In like manner, economy in cost involves limitations to heating surface and corresponding diminution in efficiency. In every case, however, it is desirable to put the heating surface into the most efficient condition, and the elements by which the designer is able to influence the quality of heating surface are enumerated as thickness of transmitting surfaces, circulation of the water and circulation of the gases.

The thickness of the surface is not a matter of very great influence upon the transmission of heat, within the limits of thickness ordinarily used in steam boilers, the condition of the surfaces being more important, and freedom from soot on one side and scale on the other are of greater moment, so that facility for keeping both surfaces clean enter into the design.

So far as circulation of the water is concerned, the vertical tubes undoubtedly have the advantage, and none of the devices used in horizontal tubes, such as inner tubes or diaphragms, circulating nozzles, etc., need be employed when the tubes are placed nearly in the vertical position. Boilers using vertical tubes are also free, in most cases, from the use of narrow and tortuous headers, so that a freer entrance and discharge may be provided.

Considering the circulation of the gases, it has already been noted that the entire duration of contact is very short, but it should be prolonged as much as possible, since the time element is an influential one. By the introduction of suitable baffle plates the gases may be prevented from passing directly to the chimney, and directed against portions of the heating surface which would otherwise receive less heat. In this respect there is not much difference between vertical and horizontal tubes,

examples of both kinds being cited in which the baffles are well arranged to prolong the duration of contact. An important matter in connection with baffle systems is their maintenance, since the presence of leaks will materially diminish their effectiveness, and in this respect the vertical tubes have an advantage.

Mr. Cummins considers that it is best to have the path of the gases as nearly at right angles to the tubes as possible, and this idea seems to be generally prevalent. It has been pointed out, however, that the direction of contact of the gases with the tubes is not a matter of great importance, since the real cause of the transfer of the heat is the difference of temperature and not the "impinging" of the gases against the metal. It is well known that vertical fire-tube boilers are fully as efficient as the horizontal variety, and the same should be true in water-tube boilers regardless of the direction of the transfer of the heat.

Summing up, Mr. Cummins says, that so far as fuel economy is concerned, a large and high combustion chamber is an absolute necessity; and that vertical tubes, as small in diameter as practicable, are preferable in all respects to horizontal ones. It is equally important that the gases, on leaving the combustion chamber to enter among the tubes, are not rushed through too quickly, but are allowed sufficient time to give up their heat. It is also desirable that the gases be split up and divided into as many narrow streams as possible.

Mr. Cummins considers at length the conditions involved in the use of water-tube boilers on shipboard, especially in connection with economy in weight, and he shows the advantages of the vertical tubes in this respect also, his views in this direction agreeing closely with those of the Admiralty boiler committee.—"The Engineering Magazine."

SUBMARINES.

Sir William White, former Chief Naval Constructor of the British Navy, an expert of international reputation, who re-

cently came to America to make a study of the condition, tendency and policy of the United States Navy, has written three papers on submarine boats for the "London Times," which are of large practical interest to naval experts everywhere. The first of these articles follows:

The construction of submarines for the Royal Navy was commenced in 1900. Five vessels were then ordered of Messrs. Vickers, Maxim & Co., who had secured from the Holland Company, of the United States, the right of building vessels similar to those which had been recently ordered for the American Navy. Mr. Holland had devoted himself to the construction of submarine vessels for more than twenty years, and this continuous effort, combined with great skill as a designer, had produced gradual improvement and eventual success. When the Navy Department invited competitive designs for submarines, it was natural, therefore, that Mr. Holland should prove successful. The construction and experimental trials of his vessel occupied a considerable time; but the Naval Commission which conducted the test experiments finally pronounced in favor of the type. Before this result was reached a new company had been formed to develop the Holland patents, and it was this company which first approached the Admiralty and subsequently arranged with Messrs. Vickers to work their patents.

The Admiralty thus insured success in preliminary orders for submarine vessels, because they acquired the accumulated experience of Mr. Holland himself, with a guarantee that further improvements made in the United States during the continuance of the agreement should be placed at their disposal through Messrs. Vickers, and the resources of that firm (whose predecessors at Barrow had built a number of submarines of the Nordenfelt type) were also secured. In addition it was decided by the Admiralty to detail an able naval officer of large experience in electrical and torpedo work to watch the construction and conduct the trial of vessels built by Messrs. Vickers, while the experience of the constructive and egineering departments at the Admiralty was made available. The

strongest possible combination was thus arranged, of all classes whose co-operation tended to produce satisfactory results in the construction, equipment and trials of the new class of vessel.

These arrangements differed essentially from those which had been adopted in France and are still employed. The French system gives free scope to the ideas and abilities of rival designers in the Génie Maritime, some of whom have individually produced new designs before the trials of their original designs were completed. It may be thought that by thus bringing many competitors into the field superior results would be obtained, but this hardly appears to have been true; nothing like an approved type has been established as yet in France, most probably because there has not been persistence in experiment and gradual improvement with any class. As the course taken by the Admiralty was in accordance with my advice, it may be thought that I can hardly deal with the subject impartially; but that there are many advantages in the Admiralty method is unquestionable, and the wisdom of the course taken in 1900 has been confirmed by subsequent experience. Delays and difficulties similar to those which have occurred abroad have been avoided, and, in a comparatively short time, a considerable number of submarines have been built and great and successive improvements have been effected, while as a group British submarines undoubtedly compare favorably with any corresponding group of foreign submarines.

It is the fashion to criticise the Admiralty for long delay before beginning the construction of submarines. This criticism when analyzed will be found to be based upon misconception or incomplete consideration of the facts. No doubt French designers have shown remarkable ability in dealing with many naval problems, and they took the lead in this branch of construction largely because the conditions under which they work give greater freedom in making new departures. That lead, however, was due to special circumstances which may be noted in passing. The construction of submarines in France proceeded in a dilatory and half-hearted fashion for several years after the *Gustave Zedé* was ordered in

1888. Her trials extended over nearly eight years and led to many modifications in details and equipment. When competitive designs for submarines were invited for the Ministry of Marine in 1896, there was no urgency or eagerness in taking action thereupon; in fact, small progress was made until an impetus to more active exertion was given by the Fashoda incident.

The French people then had pressed upon their attention the relative weakness of their Navy, and it was natural that consolation should be found in the distinct lead that they had undoubtedly obtained in submarines as the result of numerous experiments. A type had been produced which was superior to all its predecessors, and could be multiplied rapidly at a moderate cost. Twenty or thirty submarines could be produced for the price of a battleship and in much less time. Under these circumstances the cult of the submarine naturally became popular in France, especially amongst the members of the Jeune Ecole who had condemned the continued building of armored "mastodons" and advocated swift commerce-destroying cruisers. The development of submarines, it was argued, made unnecessary the continued construction of costly battleships; and submarines needed only to be supplemented for sea work by swift cruisers. These extreme views, however, did not represent the matured opinion of experienced French naval officers and naval constructors, and they were not acted upon. Many submarines were ordered, but the construction of battleships and armored cruisers went on concurrently, and the wisdom of that policy is now almost universally recognized in France.

Writers in the popular press of this country, seeking for "some new thing" to illustrate the shortsightedness and extreme conservatism of British naval authorities, waxed eloquent in condemnation of the Admiralty for long delay in taking similar action. Underlying most of these criticisms was the assumption—which was itself a fallacy—that, if foreign navies adopted submarines, it followed that the Royal Navy must possess an equal or greater force of such vessels, their numbers

being governed by the numbers of foreign vessels of similar type. In other words, it was tacitly assumed that submarines must constitute the best and necessary reply to foreign submarines. It may be worth stating, although the fact should be obvious, and the statement involves no breach of official confidence, that everything done in France and the United States from 1895 onwards in connection with submarine construction was thoroughly well known and carefully considered by the Admiralty at the time. There was no difficulty in undertaking here the design or construction of submarines had it been considered desirable to do so, and the work of building could have been done with greater rapidity; but it was decided to await developments elsewhere before making a start.

Experimental submarines had been built and tried in this country in recent years; the trials had been witnessed by officers of the Admiralty, and full information was possessed. The largest, and on the whole the best, of the submarines constructed before the introduction of storage batteries and gas engines were those of the Nordenfelt type built at Barrow-in-Furness in 1886 from designs largely due to Captain Garrett's initiative. When it became possible to use electric propulsion for the submerged condition of these vessels, in combination with gas engines for their surface propulsion, advances could be made on the Nordenfelt type, which had been fitted with steam boilers and reciprocating engines, and consequently ran risks in diving which can be avoided under present conditions. It was no pleasure trip to go under water in a Nordenfelt vessel with boilers hermetically sealed, and propulsive power dependent upon heat stored in boilers and in special water tanks provided for the purpose. But, while improvements in propelling apparatus had considerable effect on the design of submarines, it still remained true that this country had not fallen so much behind France or the United States as was affirmed, in the construction and trial of submarines. These experimental vessels were built by private enterprize, but the results were freely placed at the disposal of

the Admiralty, and the naval service benefitted by the trials. It was with this knowledge before them that their Lordships took no action up to 1900; being of opinion that the time had not yet come when it was necessary or desirable to commence the construction of submarines. Nor was there in the Navy itself at that date any marked or general desire for submarines; while in other navies, except the French, practically the same policy of waiting was adopted. In the United States a private company, not the Navy Department, pursued the investigation to a successful issue, and official action followed. Even the French did not embark upon a definite program of submarine construction until about six years ago, and the question is admittedly still in an experimental stage.

Many types were under consideration in France when the Admiralty made arrangements with Messrs. Vickers to build five vessels; but only a small number of submarines were ready for service in France at that time, and nearly all of these were avowedly restricted to coast and harbor defense. French official statements recently published show that up to 1897 the *Gymnote* and *Gustave Zedé* stood alone; in 1897–98 two more submarines were ordered, followed in 1899–1900 by ten other vessels of the submarine and submersible types. At the end of 1900 not more than five or six of these had been made available for service. In the United States there were then only two complete submarines, and it is interesting to note that in the United States Navy at the present time there are altogether only eight submarines, although a number of vessels have been constructed there for other navies during the past year. When the Admiralty ordered five submarines of the Holland type it was stated that the main purpose was to obtain experimental information first-hand in order to assess the true value of such vessels in naval warfare and to determine the best means of dealing with their attacks. The latter investigation obviously must have always the greatest importance for the British Navy, since no recognized authority would suggest that the Bristish Navy should depend largely on defensive weapons, or consist chiefly of submarines, even

if the greatest offensive power which has been claimed for the type were realized in practice. But when other navies laid down many submarines, with the declared intention of employing them for offense and defense, it was absolutely necessary that steps should be taken to ascertain the best means of foiling such attacks, and the only method available was the acquisition and experimental use of similar vessels by the Royal Navy; that plan was adopted by the Admiralty as soon as the threat became serious. Action taken at an earlier date or on other lines would have involved much larger expenditure of time and money in arriving at a decision as to type. French experience, of course, could not be made available, and it was a fortunate circumstance that at the critical moment the Holland Company came forward, placing the British Navy in a position to benefit by their experience and information, and so to start under favorable conditions on a path which has already conducted to a most satisfactory result in relative numbers and efficiency of submarine vessels under the British flag.—"Army and Navy Journal."

ALUMINUM-BRONZE CONDENSER TUBING.

Brass condenser tubing gives so much trouble that anything which will give better service must certainly receive attention. All the various brass mixtures seem to give trouble, and much time and labor have been expended in trying to improve them by the addition of tin, nickel, iron or manganese, but with little result. The verdict in regard to brass condenser tubing seems to be that it is "the nature of the beast."

A number of years ago a series of experiments were carried out upon the manufacture and use of aluminum-bronze condenser tubing, and, while they were not sufficiently extensive to demonstrate beyond doubt that this alloy is, *par excellence*, the material for condenser tubing, the results indicate that question is very promising. The experiments were made with a 4-per-cent. aluminum-bronze (96 per cent. of copper and 4 per cent. of aluminum) and the tubes left in the annealed state.

From tests made in experimental condensers and upon vessels in actual service it was found that the fault of brass tubing, *i. e.*, disintegration, was absent. It is well known that aluminum-bronze is free from disintegration and crystallization and possesses a more homogeneous structure than found in any other alloy. It is also more non-corrosive than brass.

The difficulties which have been encountered in the production of aluminum-bronze condenser tubing have been only one of manufacture, and when this has been overcome we believe that the use of this alloy for condenser tubing will be extensive.—"The Brass World."

SHIPS.

UNITED STATES.

Washington—*Launch of.*—The armored cruiser *Washington* was launched on March 18, 1905, from the yard of the New York Shipbuilding Company at Camden, N. J.

The *Washington* is a sister ship to the *Tennessee*, which is being built at the Wm. Cramp & Sons Shipyard in Philadelphia.

General Characteristics.—Displacement, 14,500 tons; length over all, 504 feet 6 inches; length on load-water line, 502 feet; beam, molded, 72 feet 6 inches; draught, 25 feet; speed, 22 knots; with a bunker capacity of 2,000 tons of coal.

Armament.—Four 10-inch breech-loading rifles, 45 calibers in length; sixteen 6-inch rapid-fire guns, 50 calibers in length; twenty-two 3-inch rapid-fire guns; twelve 3-pounder semi-automatics; two 1-pounder automatics; two 1-pounder rapid-fire guns; two 3-inch field pieces; two machine guns of .30 caliber; and six automatic guns of .30 caliber.

Armor.—A belt of armor 7 feet 6 inches wide, 5 inches thick, in wake of the engine and boiler rooms, tapering to 3 inches at the ends, extends the whole length of the vessel on the water line.

Extending vertically from the water-line armor over the main deck space, there will be an armor protection 5 inches thick for a length of 232 feet; at the end of this will be 5-inch transverse bulkheads.

The 10-inch gun turrets will have 9 inches of armor at the front, 7 inches at the sides and 5 inches at the rear, the barbettes being 7 inches at front and 5 inches at rear. The 6-inch guns will be protected by 5-inch armor.

An armored deck 4 inches thick on the sides and 1½ inches on the flat, with a cellulose belt on the side, extends the full length of the vessel.

There is a 9-inch conning tower and shield and a 5-inch armored tube.

Propelling Machinery.—The vessel will be propelled by two vertical, inverted, direct-acting, four-cylinder, triple-expansion engines with a designed I.H.P. of 23,000, when making 120 revolutions per minute. The cylinder diameters are, H.P., 38½ inches; M.P., 63½ inches; L.P. (two), 74 inches each with a stroke of 48 inches.

Boilers.—The boilers are of the Babcock & Wilcox water-tube marine type, sixteen in number, installed in eight water-tight compartments; they have a total of 1,600 square feet of grate surface and 70,944 square feet of heating surface.

St. Louis—*Launch of.*—The protected cruiser *St. Louis* was successfully launched from the yards of the Neafie & Levy Co., Philadelphia, Pa., on May 6, 1905.

The *St. Louis* belongs to the *Charleston* class. The principal dimensions are: Length on load-water line, 424 feet; extreme breadth, 66 feet; mean draught, at 9,700 tons displacement, 23 feet 6 inches; designed speed, 22 knots.

Armament.—Fourteen 6-inch rapid-fire guns, eighteen 3-inch rapid-fire guns, twelve 3-pounder semi-automatic guns, four 1-pounder automatic guns, eight 1-pounder rapid-fire guns, two 3-inch field guns, two machine guns of .30 caliber and eight automatic guns of .30 caliber.

Armor.—The main side armor, lower casemate, 6-inch gun sponsons and signal tower will be 4 inches thick; conning tower and shield, 5 inches; splinter bulkheads, 2 inches; protective deck, 2½ inches on slope and 1½ inches on the flat.

Propelling Machinery.—The main engines are two in number, of the vertical, inverted-cylinder, direct-acting, four-cylinder, triple-expansion type, with cylinder diameters as follows: H.P., 36 inches; M.P., 59½ inches; L.P. (two), 69 inches. The common stroke is 45 inches.

The engines are designed for 21,000 I.H.P., when making about 133 revolutions per minute, with a steam pressure of 250 pounds at the H.P. cylinder.

There are two main condensers, each with a cooling surface of about 13,400 square feet.

The boilers are of the Babcock & Wilcox water-tube marine type, sixteen in number, installed in four watertight compartments.

The total grate surface amounts to 1,400 square feet and heating surface to 58,800 square feet.

Minnesota—*Launch of.*—The first-class U. S. battleship *Minnesota*, of some 16,000 tons displacement, was successfully launched from the yards of the Newport News Shipbuilding and Drydock Company, at Newport News, Va., on April 8.

The *Minnesota* belongs to a class of battleships which represents the most advanced ideas in modern naval construction. With her sister ships, the *Vermont* and *Kansas*, which are also in progress of construction, the *Minnesota*, when completed, will be one of the most powerful battleships afloat. The hull of the *Minnesota* is of steel throughout, and fitted with docking and bilge keels. The general dimensions of the vessel are as follows: Length of load-water line, 450 feet; breadth, extreme, at load-water line, 76 feet 10 inches; displacement on trial, not more than 16,000 tons; mean draught to bottom of keel at trial displacement, 24 feet 6 inches; gross draught, full load, about 26 feet 9 inches; total bunker capacity, coal, about 2,200 tons; coal carried on trial, 900 tons; feed water carried on trial, 66 tons; trial speed at sea for four hours, 18 knots.

The main battery consists of four 12-inch breech-loading rifles, eight 8-inch breech-loading rifles, twelve 7-inch breech-loading rifles. The secondary battery is twenty 3-inch (14-pounder) rapid-fire guns, twelve 3-pounder semi-automatic guns, six 1-pounder automatic guns, two 1-pounder semi-automatic guns, two 3-inch field pieces, two machine guns, caliber .30; six automatic guns, caliber .30.

This battery will be mounted as follows: The 12-inch guns in pairs in two electrically-controlled, balanced, elliptical turrets on the center line, one forward and one aft, each with an arc of fire of about 270 degrees. The 8-inch guns in pairs

in four electrically-controlled, balanced, elliptical turrets, two on each beam, at each end of the superstructure.

The 7-inch guns in broadside on pedestal mounts on the gun deck, behind 7-inch armor, each gun being isolated by splinter bulkheads of nickel-steel of from 1½ to 2 inches thick; forward and after guns arranged to fire right ahead and right astern, respectively; other 7-inch guns to have the usual broadside train.

The guns of the secondary battery in commanding positions, having a large arc of unobstructed fire, and protected wherever practicable.

All the 7-inch guns will be so arranged that their muzzles train inside the line of the side armor, thus leaving a clear and unobstructed side when it is desired to go alongside a pier or vessel.

Arrangements will be made whereby the 3-inch guns on the main deck can be quickly and conveniently dismounted, housed and secured.

The hull will be protected at the water line by a complete belt of armor, 9 feet 3 inches wide, having a uniform thickness of 9 inches for about 285 feet amidships, forward and aft of which points the thickness is gradually decreased to 4 inches at the stem and stern.

The lower casemate armor will extend to the limits of the magazine spaces and reach from the top of the water-line belt to the lower edge of the 7-inch gun ports on the main deck, and be 7 inches in thickness, the athwartship bulkheads at the ends of this casemate being 6 inches thick.

There is a complete protective deck extending from stem to stern, flat amidships, but sloped at the sides throughout, and sloped at each end. It is built up of 20-pound plating throughout, with nickel-steel of 40 pounds on the flat and of 100 pounds on the slopes. Nickel-steel protection is also fitted, hatch covers, gratings, etc.

Cofferdams about 30 inches thick and extending from protective to berth-deck level will be worked from end to end of the vessel, these cofferdams being extended above the berth

deck, forward and abaft the transverse armor, to a height of about 36 inches.

The cofferdams will be packed with cellulose or other approved water-excluding material.

The magazines and shell rooms are so arranged that about one-half the total supply of ammunition will be carried at each end of the ship. Magazine bulkheads adjacent to heated compartments, such as fire rooms, engine rooms and dynamo rooms, will be arranged with air spaces.

The engines will be of the vertical, twin-screw, four-cylinder, triple-expansion type, of a combined I.H.P. of 16,500. The steam pressure will be 250 pounds. The stroke will be 4 feet. Each engine will be located in a separate watertight compartment.

There will be twelve boilers of the Babcock & Wilcox type, placed in six watertight compartments. They will have at least 1,100 square feet of grate and 46,750 square feet of heating surface, and must be able to furnish steam for the main engines and all the necessary auxiliary machinery and other steam machinery throughout the ship with an average air pressure in the fire rooms of not more than one inch of water.

There will be three funnels, each 100 feet high above the base line.

The vessel has all the up-to-date auxiliary machinery, and electrical devices, voice pipes, telephones, buzzers, gongs, indicators, etc.

There will be a lower bridge both forward and aft, and a flying bridge forward, according to the latest practice. On the flying bridge is fitted a screen of bronze for the protection of the men at the wheel, and there will also be a bronze chart house forward.

There will be steel masts forward and aft, the foremast having an upper and lower top, the mainmast a lower top only. Masts are arranged for wireless telegraphy. There will be one signal yard on each mast; also a searchlight platform forward and aft, with a crow's nest on the foremast.—"Army and Navy Journal."

Dubuque—*Trial.*—The gunboat *Dubuque* ran her speed trials off Newport, R. I., on May 10 and 11, 1905.

The vessel made eleven runs over the measured-mile course for the purpose of standardizing the propellers on May 10th, and on May 11th the full-speed trial of four hours' duration took place at sea.

The average speed for the four hours was 12.85 knots; the highest speed on the measured mile was 13.41 knots, the engines averaging 238.7 revolutions per minute.

The *Dubuque* and her sister ship, the *Paducah*, were designed for 12 knots. A detailed description of these vessels, together with the report of trials, will appear in a later issue of the JOURNAL.

Submarine Torpedo Boats Nos. 9, 10, 11 and 12—*Contract for.*—On March 6th, the Electric Boat Company of New York secured the contract for submarines *Nos. 9* and *10*, and on March 18th the same company was awarded the contract for *Nos. 11* and *12*, the boats in each case are to be built at the Fore River Ship Yard, Quincy, Mass.

The boats will be of the Holland type, the general characteristics being the same for all; *Nos. 9* and *10* will, however, have a displacement of about 261 tons when submerged, while in the case of *11* and *12* the displacement will be approximately 167 tons. The other dimensions are: Length over all, *Nos. 9* and *10*, 105 feet; *Nos. 11* and *12*, 80 feet 8 inches. Extreme beam: *Nos. 9* and *10*, 13 feet, *Nos. 11* and *12*, 12 feet 4 inches, the boats in each case being designed to withstand a pressure corresponding to submergence of 300 feet.

They are to be completed and ready for delivery within eighteen months from the date of contracts.

In addition to the standardization trials under various conditions they will be subject to the following:

(a) Four hours run in light condition with oil engine only; speed to be developed: *Nos. 9* and *10*, 10½ knots; *Nos. 11* and *12*, 8¾ knots, with an endurance capacity of fifty hours.

(b) One hour at full speed, submerged, with electric motor

only, one torpedo to be fired from each tube. Speed to be maintained: *Nos. 9* and *10*, 8½ knots; *Nos. 11* and *12*, 8 knots.

(c) A storage-battery endurance trial for three hours in awash condition at maximum capacity of motor, the battery and motor to show a capacity corresponding to a speed of 8 knots per hour in submerged condition for *Nos. 9* and *10*, and 7½ knots for *Nos. 11* and *12*.

The boats will also be required to undergo various trials to determine the time required for submergence, firing of torpedoes and endurance at sea.

Chattanooga—*Forced-Draft Run.*—The following notes are taken from a report of forced-draft run made by the U. S. S. *Chattanooga* during passage from New York to Sanchez, Santo Domingo, with three boilers in use (A, C & D).

In addition to the main engines the following auxiliary machinery was in operation:

2 dynamos.
1 evaporator.
2 main circulating pumps.
2 hot-well pumps.
2 bilge pumps.
1 main feed pump.
2 forced-draft blowers.
1 flushing pump.
Starboard auxiliary condenser.
Ice machine.

At 5·00 A. M. the port forward and starboard after forced-draft blowers were started, their speed being increased to 450 revolutions per minute at 5·30, and at the same time the auxiliary exhaust was turned into the low-pressure receivers.

The starboard counter was out of order during the run, but the engines were kept together by means of the shaft telltales.

No indicator cards were taken during the trial, but the horsepower was taken from cards obtained during the same week as trial.

In addition to the regular watch there were on duty two machinists and also one extra fireman for each boiler; the

firemen on duty from 6·00 to 8·00 were new men who had never had any experience with forced-draft operation, and it will be noted that during this time the revolutions were from 13 to 14 less than during the last two hours.

New River coal with about 20 per cent. of ash was used. Air pressure in fire rooms maintained at 1½ inches of water.

The bottom was clean, the ship having been out of dock less than one month. The opening of throttles varied from seven-tenths to full.

Cylinder cut-offs were as follows	H.P., .45; M.P., .50; L.P., .55
Average revolutions from 6·00 to 10·00 A. M.	136.7
speed (standardization curve), knots	13.28
(patent log), knots	13.67
Indicated horsepower of main engines	2,145
of auxiliaries	190
total	2,335
Coal per hour, pounds	4,896
I.H.P. per hour, main engines, pounds	2.28
total, pounds	2.10
Distance run per ton of coal, knots	6.07
Pounds of coal per mile	368.7
Draught of ship, forward, feet and inches	15–10
aft, feet and inches	15– 6

The ship was steaming in water with depth of over 2,000 fathoms, with moderate sea, one point abaft port beam, the wind on port beam with a force of 3.

...	Engines.	Revolutions per min.	Steam pressure, in pounds per sq. in.				Steam cut-off, in dec. of stroke from beginning.			Opening of throttle valve, in tenths.	Vacuum in condenser, in inches of mercury.	Pounds of coal per hour.	Temperatures, in degrees Fahrenheit.					Revs. or double strokes per minute.		Air pressure, in inches of water.
			In boilers.	At engines.	In receiver above a per. vacuum.		H.P. cyl.	I.P. cyl.	L.P. cyl.				Engine room.	Fire room.	Injection water.	Discharge water.	Feed water.	Circulating pump.	Fire-room Blowers.	
					1st.	2d.														
A. M.																				
6		...	165	160	28	12	.45	.45	.45	3	27	3,264	90	100	77	87	193	130	450	1½
7	Stbd.	...	155	150	51	17	.45	.45	.45	5	27	3,672	90	110	77	90	140	140	450	1½
8		...	145	14	52	17	.45	.45	.45	7	27.5	2,652	90	110	77	90	138	130	450	1½
		..	195	190	60	24	.45	.55	.60	full	27	6,120	95	110	78	94	174	130	450	1½
10		...	195	190	58	24	.45	55	.60	full	27	6,120	95	110	78	94	175	130	450	1½
6		100.5	165	160	53	17	.45	.50	.55	6	27	...	90	100	77	87	191	130	...	...
7	Port.	129.7	155	150	53	17	.45	.50	.55	9	27	...	90	110	77	90	140	140	...	...
8		128.5	145	140	53	16	45	.50	.55	7	27	...	90	110	77	90	138	130	...	...
9		144.2	195	19	70	18	45	.50	.55	10	27	...	92	110	78	90	180	130	...	...
10		141.2	195	190	65	17	.45	.50	.55	10	27	...	92	110	78	90	180	130	...	...

AUSTRO-HUNGARY.

The official trial of the Austro-Hungarian battleship *Erzherzog Karl* took place off Pola on May 3, 1905; 14,000 H.P. was contracted for, and a speed of 19¼ knots. The trial resulted in 16,000 H.P. being developed, and the speed was 20 knots. The machinery for this vessel was constructed by the Stabilimento Tecnico, Trieste, water-tube boilers of the Yarrow large-tube type being adopted.

ENGLAND.

Cochrane—*Launch of.*—On Saturday, May 20th, the armored cruiser *Cochrane* was launched from the works at Glasgow of the Fairfield Shipbuilding and Engineering Company, Limited. The contract was completed in September, 1903, the keel laid on March 24, 1904. The *Cochrane* is of the following dimensions: Length between perpendiculars, 480 feet; breadth, extreme, 73 feet 6 inches; and displacement at load draught, 13,550 tons. There is an armored belt extending all round, consisting of 240-pound armor, tapering to 80 pounds at the fore end and 160 pounds at the aft end of the vessel. The protective deck proper extends from the stem to the stern, and ranges in weight from 80 pounds to 30 pounds per square foot. This deck is worked at the lower edge of the armor, and protects the vitals of the ship. Another deck of 40 pounds per square foot forms a crown over the side armor and armor bulkheads. The normal coal capacity is about 1,000 tons.

The armament will be six 9.2-inch breech-loading guns and four 7.5-inch breech-loading guns, all fitted to revolve in barbettes, the guns being worked and loaded by hydraulic power. The secondary armament consists of twenty-eight 3-pounder quick-firing guns and two 12-pounder guns. The supply of ammunition for these guns will be hoisted by means of electric motors. Two Maxim guns will also be provided. In addition, the vessel has two under-water 18-inch broadside torpedo tubes and one under-water stern 18-inch torpedo tube. At the fore end there is provided a steel conning tower of 10 inches thickness, with an armored communication tube to a lower

conning tower. Wireless telegraphy on the latest methods will also be supplied. An electric installation is arranged throughout the vessel on the double-wired system, and includes six powerful searchlights.

The propelling machinery consists of two sets of triple-expansion engines, arranged in two watertight compartments. Each set has four inverted cylinders working on four cranks. The crank, thrust and propelling shafting is of forged steel and hollow. The two propellers are of manganese-bronze, and each has three adjustable blades which work outwards when the vessel is going ahead. The main condensers are of oval form, made of gun metal and fitted with brass tubes, and the condensing water is supplied by four centrifugal pumps of gun metal, each fitted with one independent engine. Steam will be supplied by nineteen Yarrow water-tube and six single-ended cylindrical boilers. All are designed to work at a pressure of 210 pounds. The vessel on trial is to develop 23,500 indicated horsepower, and a speed of 23 knots is expected to be obtained. Her complement is about 700 officers and men.

Africa—*Launch of.*—On the same day, May 20th, H. M. S. *Africa* was launched from the Chatham Dockyard. The first keel plate was laid on January 27, 1904. The principal dimenmensions of the ship are: Length between perpendiculars, 425 feet; breadth, extreme, 78 feet; freeboard—at stem, 22 feet; at amidships, 16 feet 6 inches; at stern, 18 feet; draught—forward, 26 feet 3 inches; aft, 27 feet 3 inches. The displacement at load draught is about 16,350 tons. The hull is constructed of steel plates and bars on the bracket system; the stem, sternpost, rudder frame, shaft brackets, &c., being steel castings. On the side, extending from about 5 feet 3 inches below to 8 feet 6 inches above the water-line, the armor consists of Krupp steel, 9 inches and 8 inches thick amidships; 7 inches, 5 inches and 4 inches forward. At the after end of the belt is a rounded armor bulkhead of 12-inch, 10-inch and 8-inch Krupp steel. Above this belt, amidships, is the battery, which is formed of 7-inch Harveyed steel, splinter bulkheads, 2 inches thick, of K.N.C. plating, being fitted be-

tween 6-inch gun positions. There are also 2-inch nickel-steel plates on bow and stern. The two barbettes for 12-inch guns are circular in front, the upper tiers of plates being 12 inches thick, the lower 8-inch and 6-inch Krupp steel. The conning tower is of 12-inch and 10-inch Krupp steel. The upper deck is formed of two thicknesses of ½-inch plating within the citadel, but only a single thickness of ⅜-inch before and abaft the latter. The main deck has two thicknesses of 1-inch plating from the forward battery bulkhead to about Station 22; from here to stem it is formed of two thicknesses of ¾-inch plating, the remainder being generally one thickness of ⅜-inch plating. The middle deck has two thicknesses of ½-inch plating from the armored bulkhead to the fore side of the forward barbette, where it slopes to the lower deck in two 1-inch plates. The slope on the side over the main machinery compartments is also formed of two 1-inch plates. The lower deck from the slope of the middle deck to the stem is made of two thicknesses of ½-inch plating; and from the armor bulkhead to the after end of the ship, two thicknesses, one of 1-inch and the other of 1½-inch plating.

The armament includes four 12-inch 50-ton breech-loading guns, on two turntables in circular barbettes, with all-round loading. The guns are protected by shields formed of 8-inch and 10-inch Harveyed steel plate, the floor and crown plates being 2-inch and 3-inch armor plating. There are also four 9.2-inch 28-ton breech-loading guns on turntables in circular barbettes, ten 6-inch Mark XI guns in battery on main deck, and twelve 12-pounder 18-cwt. guns—four on upper deck and eight on shelter deck; fourteen 3-pounder Hotchkiss—two on upper deck, eight on 9.2-inch shields and four on forward bridge; two 12-pounder 8-cwt. guns on after shelter deck, and two Maxim guns mounted on tripod stands. There are four submerged tubes for 18-inch torpedoes—two on forward platform deck and two on after platform deck. The ship carries eighteen 18-inch torpedoes and six 14-inch torpedoes, these latter for firing with dropping gear from ship's steamboats. The complement of officers and men is 781. The total capacity

of coal is 2,200 tons. This amount of coal will enable the ship to steam for about twenty-nine days at a speed of 10 knots, or about four and a half days at 18½ knots.

Messrs. John Brown & Co., Limited, of Clydebank, are the contractors for the machinery. There are eighteen Babcock & Wilcox type boilers, fitted in three boiler rooms, six in each; and three cylindrical boilers, each 15 feet 7⅞ inches external diameter and 10 feet 7 inches long, with three furnaces, 3 feet 11 inches internal diameter, of Brown's cambered type, are fitted in a fourth boiler room. The safety valves to all boilers are to be loaded to 210 pounds per square inch. The engines are of 18,000 indicated horsepower, there being two sets of inverted four-cylinder triple-expansion engines, working at a pressure of 205 pounds per square inch. The diameters of the cylinders are: High-pressure, 38 inches; intermediate pressure, 60 inches; low pressure, 67 inches each. The four main condensers are of brass. The propellers are 16 feet in diameter, ard are arranged so that the pitch may be varied. There are also in the engine rooms four evaporators, four fire and bilge pumps, each capable of discharging 100 tons of water per hour; four main centrifugal pumps, each capable of discharging 1,400 tons of water per hour from the bilge; two twin air pumps driven by independent engines (one in each engine room); two turning engines and two starting engines. In the boiler rooms are eight feed pumps (four main and four auxiliary). Outside the main machinery spaces are four dynamos—two on the lower deck and two on the middle deck, each producing a current of 600 ampères with an electromotive force of 105 volts. There is one ice-making machine in the auxiliary-machinery compartment on lower deck capable of producing 80 pounds of ice in 24 hours under tropical conditions. Four sets of air compressors—two aft and two forward—are fitted on the lower deck for charging and ejecting torpedoes. There is a steam capstan forward, the after capstan being worked by an electric motor.

The steering gear is of the screw type, with two steering engines, one in each engine room. Either engine is of suffi-

cient power to put rudder from hard over to hard over (or through 70 degrees) in 30 seconds when the ship is proceeding at full speed of 18½ knots. There are four steering positions, viz: fore bridge, conning tower, lower deck forward, and steering compartment on platform deck aft. The 12-inch and 9.2-inch guns are worked by hydraulic machinery, supplied by two pumps. The ship is fitted with six searchlights—two on the masts, two on the forward bridge, and two on the platforms near the after shelter-deck. There are twelve steam fans for ventilating the boiler rooms, twenty-six fans for the general ventilation of the ship, and eight fans for ventilating the engine rooms, driven electrically. The ship has two steel masts, 2 feet 6 inches in diameter, each mast being fitted with a searchlight platform and striking topmasts, each topmast being 146 feet above the waterline, with a multiple-fiber flashing-signal lamp at the fore, and a truck semaphore at the main.

There are sixteen boats provided for the ship: two 56-feet steam pinnaces, one 40-foot steam barge, one 42-foot launch, one 36-foot sailing pinnace, two 34-foot life cutters, one 30-foot cutter, one 32-foot galley, one 30-foot gig, one 28-foot gig, three 27-foot whalers, two 16-foot skiff dinghies. When the boats are armed, the 40-foot steam barge, the 56-foot steam pinnaces and the 36-foot sailing pinnace will each carry one 3-pounder Hotchkiss gun; the 42-foot launch, one 12-pounder 8 hundredweight gun, and each of the 34-foot cutters will carry a 0.303-inch maxim. The steamboats and the 42-foot launch will be fitted with countermining gear, and the 56-foot steam pinnaces with dropping gear for firing 14-inch torpedoes. The weight of hull, &c., when the ship is launched, will be about 5,800 tons.—"Engineering, London."

H. M. S. Forward.—*H. M. S. Forward*, the first of the two scouts built by the Fairfield Company for the British Navy, completed on May 11th her official steam trials, when she realized, as a result of six runs over the measured mile at Skelmorlie, a mean speed of 25.286 knots when developing 14,995 indicated horsepower. The Fairfield Company guaranteed in their contract with the Admiralty a speed of 25 knots, the de-

signed power being 16,500 indicated horsepower. With a length between perpendiculars of 365 feet and a beam of 38 feet 9 inches, the Fairfield scouts displace 2,850 tons when the draught is 14 feet 2 inches. At this draught 150 tons of coal were in the bunkers, sufficient to carry the vessel 1,500 nautical miles at 10 knots. There is, however, capacity for 500 tons of coal, which gives a radius of action of 5,000 nautical miles at the same speed. The attainment of 25 knots involves a high rate of combustion in the twelve boilers, which are of the modified Thornycroft type. On the official full-power trial the air pressure in the stokehold was under 2 inches, which is moderate for such craft. The boilers, when working under these easy conditions, supplied adequate steam for the engines, which are of the four-cylinder triple-compound type, driving twin screws. The summation of the results, taken each hour on the eight-hours' test, showed that the revolutions averaged 210 per minute, and that the mean power was 15,022 indicated horsepower. The air pressure in the stokehold was 1.8 inch, and the average steam pressure at the boilers 250 pounds, and at the engines 230 pounds. The vacuum was 25 inches. Over the whole eight hours, therefore, the speed was quite 25¼ knots, so that, as already stated, the guaranteed rate was exceeded with a power 1,500 less than was anticipated.—"Practical Engineer."

New Zealand.—The steam trials of the *New Zealand*, battleship, which have just concluded, were very satisfactory. Whilst they were in progress only the usual steaming complement was allowed in the engine room, and the use of water to cool the bearings was dispensed with. The records taken during the 30-hours' trial at a mean collective indicated horsepower of 3,938 were as follows: Draught, 26 feet 3 inches forward, 27 feet 3 inches aft; steam in boilers, 186 pounds; vacuum, 27 starboard, 27 port; revolutions per minute, 70 starboard, 71.1 port; mean total indicated horsepower, 1,936 starboard, 2,002 port; speed, 9 knots; coal consumption, 2.02 pounds per indicated horsepower; total loss of water, 14½ tons. The results of the thirty-hours' trial at 12,918 mean collective indicated

horsepower were as follows: Draught, 26 feet 3 inches forward, 27 feet 3 inches aft; vacuum, 26.7 starboard, 27.2 port; revolutions per minute, 108.7 starboard, 27.2 port; mean total indicated horsepower, 6,360 starboard, 6,558 port; speed, 16.9 knots; coal consumption, 1.84 pounds per indicated horsepower; total loss of water, 26 tons. Eight-hours' full-power trial: Draught, 26 feet 4 inches starboard, 27 feet 3 inches port; steam in boilers, 197 pounds; vacuum, 25.5 starboard, 26.5 port; revolutions per minute, 120.1 starboard, 121.6 port; mean total indicated horsepewer, 9,084 starboard, 9,299 port; mean collective indicated horsepower, 18,383; speed, 18.59 knots; coal consumption, 2.1 pounds per hour; total loss of water, 12.4 tons.—"Practical Engineer."

King Edward VII—*Steam Trials.*—The *King Edward VII* entered the new *King Edward* dock at Gibraltar on the afternoon of her arrival, a notable event in the annals of the Rock, as she is the first battleship to enter one of the new graving docks. The recent steam trials of the ship supply material for comparison between the water-tube boilers of the ship and the cylindrical boilers with which she is also fitted. At one-fifth of her power the Babcock & Wilcox boilers gave 66.4 revolutions and 3,759 I.H.P., with a coal consumption of 1.74 pounds per I.H.P. per hour. The corresponding figures for the cylindrical boilers were 65.2 revolutions, 3,634 I.H.P. and 1.8 pounds coal consumption. At full power the water-tube boilers gave 198 revolutions, 7,510 I.H.P. and 1.67 pounds coal consumption; while with the cylindrical boilers the readings were 190 revolutions, 6,686 I.H.P. and 1.88 pounds coal consumption. The result of these trials is to show clearly the inferiority of the cylindrical boiler, and will probably prove the death knell of any further attempts to bolster up that now obsolete type of steam generator.—"Exchange."

Garry—*Trial of.*—H. M. torpedo-boat destroyer *Garry*, the last of six destroyers of the new type being built by Messrs. Yarrow & Co., Poplar, for the British Admiralty, was launched on March 21, 1905, and had her full-speed trial on May 2. The result has been awaited with special interest, because the

shape of this vessel differs considerably from that generally adopted, the after part resembling somewhat the design now common for racing motor boats, the breadth amidships being continued nearly the full width to the stern. The counter thus extends considerably over the propellers, thereby protecting them from damage, and at the same time admitting of more commodious living spaces for the officers without exposing a greater length to gun fire. The rudder, instead of being secured to the stern, as is customary, has its entire surface below the waterline, and therefore is not exposed. The keel is perfectly straight from end to end, the overhang of the stern being of such short dimensions that no special support is necessary, thus simplifying docking operations. The coal-carrying capacity of this form of hull is greater than is usual in the "River" type of destroyer to the extent of 20 tons. These advantages are obtained in combination with a diminished resistance, as the recent trial indicates, the speed attained being 26½ knots, that of other destroyers of the same class varying from 25½ to 26 knots. The dimensions of these vessels are as follows: Length, 225 feet; beam, 23 feet 6 inches. They are fitted with four-cylinder triple-compound engines and four Yarrow boilers. The engines of these vessels are balanced on the Yarrow, Schlick and Tweedy system.

Chelmer—*Trial of.*—H. M. S. *Chelmer* returned to Southampton recently from the Clyde, where she has carried out her official speed and radius-of-action trials. She is the second vessel to complete her trials out of the fifteen similar ships ordered under the Navy Program of 1903–4. The *Chelmer* is a twin-screw torpedo-boat destroyer of the 25½-knot River class. Length, 225 feet; beam, 23 feet 10½ inches; displacement, 550–600 tons; I.H.P., 7,500–8,000. She was ordered from Messrs. John I. Thornycroft & Co., Ltd., on November 24, 1903, and was built at their Chiswick yard, and has now returned to their Southampton works to receive her sea stores and equipment, and for examination before handing over to the naval authorities.—"Page's Weekly."

Boyne—*Trials of.*—Two official trials by the Admiralty of

the torpedo-boat destroyer *Boyne* have recently been carried out. The first—a full-speed coal-consumption trial—took place on March 10, and the results obtained were so satisfactory as to enable arrangements to be made for the full-power official trial, which took place on March 24th. While running under the Admiralty conditions for the guaranteed speed of 25½ knots she attained an average speed over the four hours of 25.73 knots, thus exceeding her guarantee by nearly a quarter of a knot.

Submarines—*Contracts for.*—Messrs. Vickers have recently received from the Admiralty an order for ten submarines. These boats are to be of a more formidable type, will be more easily submerged and will have greater speed than any built up to the present time.

China Squadron—*Steam Trials.*—The report of the steam trials at sea of the China Squadron is just to hand, and on the eight-hours' run every ship did well, exceeding the official contract speeds, although most of the vessels have been three or four years in commission. The best cruiser speed was got with the *Amphitrite*, built by Vickers, which attained a mean on her eight-hours' sea trial of 21.39 knots, as compared with the designed speed of 20.75 knots. Next comes the *Andromeda*, a dockyard-built ship, engined by Hawthorn, Leslie & Co., which steamed 20.1 knots, only 0.15 miles below the contract rate. Of battleships the *Vengeance*, also a Vickers ship, takes first place, with a speed on the eight-hours' set trial now of 19.10, against the designed speed of 18.25 knots. The other ships are the *Albion*, by the Thames Iron Works, which steamed 18.7 knots; the *Glory*, by Laird, which got 18.6 knots, and the *Ocean*, engined by Hawthorn, Leslie & Co., which got 18.83 knots. The designed speed in these three cases was 18¼ knots. Practically all of these ships have the Belleville boiler.—"The Practical Engineer."

Pathfinder—*Trial of.*—The H. M. S. *Pathfinder*, one of two scouts built by Messrs. Cammell, Laird & Co., Birkenhead, for the British Navy, has now completed her official coal-consumption and speed trials. The coal-consumption trial

was of ninety-six hours' duration at a cruising speed of about 11 knots. This trial was entirely satisfactory from the point of view of economy. The vessel proved herself capable of a radius of action of about 6,000 knots, which is largely in excess of the requirements of the contract. The eight-hours' full-power trial took place over the measured mile at Skelmorlie on Saturday, April 8th, when a mean speed of 25.48 knots was obtained on the six runs on the mile, and 25.38 knots for the whole time. The guaranteed speed was 25 knots. The vessel proved herself an excellent sea boat.—"Engineering," London.

Submarines—*Launch of.*—On March 8th Messrs. Vickers, Sons & Maxim launched from their yard at Barrow two submarines of the "A" class.

Swale—*Launch of.*—Messrs. Palmer & Company launched on April 10th, from their shipbuilding yard at Jarrow, the torpedo-boat destroyer *Swale*, built for the Admiralty. Her displacement is 565 tons. She will have engines of 7,000 horsepower, and the guaranteed speed is 25½ knots. She is the twenty-fifth destroyer built by the firm for the Admiralty. The first, the *Janus*, was launched eleven years ago. A speed of 27 knots was made by the first three vessels; then came the *Star*, the first of their 30-knot boats. The *Swale* will, like her sister ships, the *Wear* and the *Ure*, now completing, have engines fitted with a system of forced lubrication, and these, with the exception of a destroyer built for the Admiralty some time ago, are the only vessels in the Navy so fitted.—"Practical Engineer."

Spiteful—*Accident to.*—The destroyer *Spiteful* recently, while steaming at a speed of about twenty knots, ran into and practically passed over a barge laden with bags of cement. The bows were stove in, but her light build considerably minimized the force of the shock she gave, as it were, to the impact and was kept afloat until placed in drydock.

A5—*Cause of Accident to.*—The official inquiry held by Captain R. H. S. Bacon and Dr. B. Redwood, F. R. S. E., on behalf of the Admiralty into the explosion on board the sub-

marine *A5*, which occurred in Queenstown Harbor on the 16th of February, has shown that the accident was due to carelessness and not to any danger that had not up to then been known. The cause of the explosion was shown by the evidence to be due to petrol vapor escaping and becoming ignited by the sparking from the electric motor. A strong smell of petrol was observed some hours before the explosion occurred, caused by the leakage from the petrol pump, due to insufficient packing in the plunger-rod gland. The ventilating fans were started, but apparently the leakage was still going on. The chief engine-room artificer, who had been working at the propeller clutch, was giddy from the smell of the petrol, and had to go forward for fresh air. In spite of this the motors were deliberately started to revolve the engines to exhaust the air, preliminarily to descending below the surface. The sparking of the brushes supplied the necessary ignition of the mixture, and the explosion occurred. The action of starting the motor under such circumstances is described by Captain Bacon as a "flagrant violation of the regulations laid down." It is obvious that in cases where petrol motors are used in confined spaces for driving dynamos, such as motor 'buses and the combined automobile carriages on the North-Eastern Railway, great care must be taken to prevent any leakages of petrol vapor and the consequent forming, on mixing with the air, of a highly explosive mixture, easily ignited by a spark.—"The Practical Engineer."

Destroyer.—It is reported that the British Admiralty intend building a sea-going destroyer, having a displacement of about 700 tons, to be fitted with turbine engines and designed for a speed of 36 knots.

British Shipbuilding.—The following is from the statement of the First Lord of the Admiralty, explanatory of the naval estimates, 1905–1906:

Between 1st April, 1904, and 31st March, 1905, inclusive, the following ships will have been completed and become available for service: Four battleships, *King Edward VII*, *Commonwealth*, *Swiftsure* and *Triumph;* one armored cruiser,

Cornwall; four third-class cruisers, *Sapphire*, *Diamond*, *Topaze* and *Amethyst;* twelve submarines, nine destroyers, four torpedo boats, one river gunboat and a new Admiralty yacht.

On 1st April, 1905, there will be under construction: Eight battleships, fifteen armored cruisers, one second-class cruiser, one third-class cruiser, eight scouts, eighteen destroyers, eleven submarines.

It is proposed to begin during the financial year 1905–1906: One battleship, four armored cruisers, five ocean-going destroyers, one ocean-going destroyer of an experimental type, twelve coastal destroyers and eleven submarines.

Obsolete Ships—*Sale of.*—There was an immense concourse of buyers and spectators recently at the sale of obsolete war vessels at Chatham dockyard and the amount realized was over $690,000. Of the thirty vessels and other ships offered by auction, four were first-class cruisers, one a third-class battleship, three second-class cruisers and five third-class cruisers. The *Simoom* fetched $72,750; the *Warspite*, $90,750; *Northampton*, $79,000; *Arethusa*, $38,000; *Galatea*, $55,750; *Australia*, $54,500; *Severn*, $35,500; *Mersey*, $36,000; *Barracouta*, $20,000; *Exmouth*, $20,750; *Archer*, $24,250; *Cossack*, $24,000; *Mohawk*, $24,250; *Raccoon*, $20,750. The *Royal Adelaide*, hulk, fetched $17,500. "The Military and Naval Record" of April 6, says of this sale: "In connection with the sale of condemned warships, it is interesting to be reminded of the gigantic expenditure upon the battleship *Sultan* since she sank in the Comino Channel. This ship was completed in 1871 at a cost of $2,532,275, and she was considered a rather costly vessel for that period. Raising and repairing the ship cost $1,024,565, and it was considered by many naval officers at the time that the expense was not justified. Since then the money spent upon the *Sultan* has amounted to $662,850, so that her total cost to the nation has been nearly a million sterling. If memory serves us rightly, even more than a million was spent upon the *Inflexible*, the building of which was much delayed. The sale this week of

unserviceable ships is likely to revive attacks upon the government, based upon expenditure incurred in the repair of ships now admitted to be either worn out or virtually obsolete. The government must submit to these strictures with becoming meekness, for it is an unquestionable fact that much money has thus been wasted."—"Army and Navy Register."

The vessels would undoubtedly have brought a better price but for the fact that, by the terms of the sale, they are to be broken up within a year.—(EDITOR.)

FRANCE.

Added to the Effective List.—The following vessels were added during 1904:

First-Class Armored Cruisers.—Amiral Aube, *Gloire* and *Condé*, all of 10,000 tons, 20,000 I.H.P., and 21 knots speed: *Desaix*, *Kleber*, of 7,735 tons, 17,000 I.H.P. and 21 knots speed.

Torpedo-Boat Destroyers.—Arc, *Baliste*, *Bélier*, *Dard*, *Francisque*, *Mousqueton*, *Sabre*, *Sarbacane*, all of 303 tons, with a speed of from 28 to 30 knots. These vessels are the last of their type to be completed. The new destroyers of the *Claymore* class are about 50 tons larger, and are to have a speed of 30 knots.

Eleven torpedo boats, up to No. 292, and eight submarines of the 68-ton class.

The principal ships completing or under trial are:

First-Class Battleships.—Répulique, launched at Brest, 4th September, 1902; *Patrie*, launched at La Seyne, 17th December, 1903; *Démocratie*, launched at Brest 1st May, 1904; *Justice*, launched at La Seyne, 27th October, 1904; all of 14,865 tons, 18,000 I.H.P. and 18 knots speed.

First-Class Armored Cruisers.—Léon Gambetta, launched at Brest 26th October, 1901 (has commenced her trials); *Jules Ferry*, launched at Cherbourg, 28th August, 1903 (to be ready for her trials by the middle of present year); *Victor Hugo*, launched at Lorient 30th March, 1904; all of 12,550 tons, 27,500 I.H.P. and 22 knots speed; *Dupetit Thouars*, launched

at Toulon, 5th July, 1901, of 9,516 tons, 19,600 I.H.P. and 21 knots speed (has now recommenced her trials, which were interrupted last March, owing to her having strained her hull).

The following large vessels are building:

First-Class Battleships.—Liberté, at St. Nazaire; *Vérité*, at Bordeaux; both of 14,865 tons, 18,000 I.H.P. and 18 knots speed.

First-Class Armored Cruisers.—Jules Michelet, at Lorient, of 12,550 tons, 27,500 I.H.P. and 22 knots speed; *Ernest Renan*, at Penhoet, St. Nazaire, of 13,562 tons, 40,000 I.H.P. and 23 knots; *Edgard Quinet*, at Brest, just laid down, of 14,300 tons, 40,000 I.H.P. and 24 knots speed.—"Journal of the Royal United Service Institution."

Léon-Gambetta—*Trials of.*—The repairs of the new first-class armored cruiser *Léon Gambetta*, rendered necessary by her mishap last month, have been rapidly carried out, and she has now at last successfully completed her trials, which were interrupted more than a year ago by the injuries the ship sustained through striking a pinnacle rock when steaming at high speed. The first trial was a preliminary one, and lasted eleven hours; only the central engine and four boilers were used, the results being satisfactory. The second preliminary trial was at high speed, the engines having to develop 25,000 I.H.P., or nine-tenths of her full power; this trial was for two hours, and the results were very satisfactory, the engines developing 26,200 I.H.P., 1,200 in excess of contract, the mean speed being 22.1 knots. During the 24-hours' coal-consumption trial the engines developed 16,911 I.H.P., giving a speed of 20.4 knots, with a coal-consumption of 761 gr. (1.52 pounds) per H.P. per hour. At the three-hours' full-speed trial the engines developed a maximum of 30,500 I.H.P., or 3,000 H.P., over the contract, and a mean of 29,008 H.P., giving a maximum speed of 24 knots—two knots over the contract—and a mean of 23.1, with a coal consumption of 176 kg. (387.9 pounds) per square meter of grate surface; the boilers of the large-tube Niclausse type worked most satisfactorily the whole time. The *Léon Gambetta* has thus proved

herself the fastest cruiser as yet built for the French Navy, and she is the first large cruiser of the 12,600 type of the 1900 program, brought in by M. de Lanessan, to be completed. —"Journal of the Royal United Service Institution."

Dupetit-Thouars—*Trial of.*—The *Dupetit-Thouars*, a new French armored cruiser of 9,600 tons, 19,600 indicated horsepower, built at the Toulon Naval Yard, has recently completed her steam trials. Her machinery, supplied by Messrs. Schneider & Co. of Creusot, consists of three independent, vertical, three-cylinder, triple-expansion engines of equal power, each working a propeller. They are supplied with steam from twenty-eight Belleville boilers. These have a total of 113 square meters (1,216 square feet) grate area; a total heating surface of 3,580.04 square meters (38,540 square feet), and are subjected to a test pressure of 20 kilograms (294 pounds) per square inch.

The four series of trials made were the following:

1. *Coal Consumption on Trial at 1,800 Horsepower.*—According to the terms of the contract, this trial was to extend over six hours, the coal consumption to be from 650 to 700 grammes (1.4 pounds to 1.5 pounds) per horsepower hour.

The actual consumption during the trial amounted to but 519 grammes (1.1 pounds) per horsepower hour, thus showing a very satisfactory saving, the result of which will be to increase in a marked degree the radius of the action of the ship.

2. *Coal-Consumption Trial at 14,000 Horsepower.*—This was carried out on January 6, and lasted six hours. The consumption contracted for was 750 to 800 grammes (1.6 to 1.7 pounds) per horsepower hour. The actual consumption only amounted to 559 grammes (1.2 pounds) per horsepower hour.

3. *Maximum Power Trial.*—This was delayed for about one month, owing to slight damage sustained by the hull, the ship, under the action of a high wind, having come foul of the dock wing walls. The portside false keel was also torn by coming in contact with a mooring buoy. These damages were made good, and the trials were resumed on February 14.

The conditions to be fulfilled on this occasion were the following: Duration, three hours; power to be obtained, 19,600

horsepower; combustion per square meter of grate area to be 160 kilograms (32.8 pounds per square foot) per hour.

The results obtained largely exceeded all expectations. The power developed reached 22,000 horsepower, while the rate of combustion did not exceed 140 kilogrammes per square meter of grate area (28.6 pounds per square foot) per hour.

The runs made on the new measured mile at the Hyères island in the Mediterranean showed an average speed of 22.05 knots, instead of the 21 knots contracted for.

4. *Trial at Normal Power (10,000 Horsepower).*—A recent naval order specifies that this trial, which lasts over twenty-four hours, has to take place not later than three days after the maximum power trial. The coal consumption contracted for was 750 to 800 grammes (1.6 pounds to 1.7 pounds) per horsepower hour. The actual results obtained were no less favorable than those of the preceding trials. The coal consumption amounted to but 590 grammes (1.3 pounds) per horsepower hour.

The admiral in charge of the trials expressed himself most highly satisfied with the performance of the ship. The results obtained and recorded above reflect the highest credit upon Messrs. Schneider & Co., and the Delaunay-Belleville Company.—"Engineering," London.

Liberté—*Launch of.*—On the 19th of April the latest of the French battleships was launched from the yards of the Ateliers et Chantiers de la Loire, near St. Nazaire. This ship is one of the *République* class of six ships, which will form a very powerful squadron in the French fleet, and will be distinctive from most of the other ships in that fleet, not only on account of the fact that they are the largest ships yet designed for the French Navy, but because of the fact that they are identical in design, whereas preceding ships have in almost every instance been of heterogeneous design, even though built at the same time and given approximately the same elements of military value. Being one of the latest of the *République* class, however, there are a number of improvements incorporated in the *Liberté* which are more in the nature of details

than in the main features of the design. One alteration, however, which is of great importance, is the substitution of ten 7.7-inch guns for the sixteen 6.4-inch guns in the earlier ships. The *Liberté* embodies a thoroughly well-studied compromise of all the requirements imposed upon the designer of a modern battleship.

Navy	England.	United States.	France.	Germany.	Italy.	Russia.	Japan.
Ship	*King Edward VII.*	*Kansas.*	*Liberté.*	*Deutschland.*	*Vittorio Emanuele III.*	*Imperator Paul I.*	*Kashima.*
Displacement, tons	16,350	16,000	14,750	13,000	12,630	16,630	16,400
Length, L. W. L.	425 ft.	450 ft.	440 ft.	400 ft.	435 ft.	425 ft.	455 ft.
Beam, extreme	78 ft.	76 ft. 10 in	79 ft. 6 in.	72 ft.	73 ft. 6 in	78 ft.	78 ft. 2 in.
Draught, mean	26 ft. 9 in	24 ft. 6 in	27 ft. 6 in.	25 ft. 9 in.	25 ft. 10 in	27 ft.	26 ft. 4 in.
Horsepower	18,000	16,500	*18,000	*16,000	*21,000	18,000	21,500
Speed in knots	18.5	18	18	18	21	18	18.5
Armor, water line	9	9	11	9	10	11	9
for'd, aft.	6— 3	4— 4	6— 6	7 and 4	6 and 4	6— 6	6.5— 6.5
citadel	8	7	10	5.5	8	?	6
casemate	7	7	6	6.75	None.	None.	6
deck	2	3	2— 3	3	4	2 75— 4	3
barbettes	12	10	11	10	10	12	9
turrets	12— 7	10— 6	12— 5	11	10— 6	12— 7	9— 5
Main battery	4-12 in. 4- 9.2 in. 10- 6 in	4-12 in. 8- 8 in. 12- 7 in.	4-12 in 10- 7.7 in. ...	4-11 in. 14- 6.7 in ...	2-12 in. 12- 8 in. ...	4-12 in. 12- 8 in. ...	4-12 in. 4-10 in. 12- 6 in.
Secondary battery	14-12 lbr. 14- 3 lbr. 2 mach. ...	20- 3 in. 12- 3 lbr. 8- 1 lbr. 12 mach.	16- 3 lbr. 16- 1 lbr.	22- 3.4 in. 6- 3 lbr. 16 mach. ...	12- 3 in. 12- 3 lbr. 4 mach. ...	?	12-12 lbr. 12- 3 lbr. 6 mach. ...
Torpedo tubes	5-18 in.	4-21 in	5-18 in.	6-18 in.	4	4	5
Coal supply, tons	950-2,600	900-2,200	900-1,850	800-1,800	1,000-2,600	?	1,200-2,000
Crew	800	800	750	700	700	900	980

*Three screws.

In order to institute a comparison between the principal data of this ship and those of the latest battleships of other powers there is appended a table giving the principal characteristics of one battleship from each of the seven leading naval powers of the world, from which it is seen that the *Liberté* makes a very commendable showing in comparison with most of the others. If we compare her with the *Deutschland* of the German Navy, or the *Kansas* of the United States Navy, it is seen that her powerful guns could inflict serious damage upon the relatively thin water-line belts of these hypothetical enemies, while her own 11-inch armor belt would render her almost invulnerable to shells from the other ships. The same

holds true when we compare her with the English *King Edward VII* and the Japanese *Kashima*, except for the fact that the two latter ships have one knot greater speed, and could therefore engage or not at will, or could choose the distance best suited to themselves in case an engagement was found desirable.—"Marine Engineering."

Aigrette and "Z"—*Comparative Trials.*—The "Moniteur de la Flotte" gives interesting particulars of the comparative trials of the submersible *Aigrette* and the submarine *Z*. The object was to take account of technical considerations touching surface navigation, habitability and, in particular, the method of plunging, and the time occupied in the operation. The *Aigrette* proved her absolute superiority when navigating on the surface, for she rose easily to the waves, and permitted her crew to enjoy a considerable degree of comfort. The *Z*, on the contrary, made heavy by her bridge, did not do so well. She has four torpedo tubes forward, which, when they are charged with torpedoes, add some two tons to the weight, this making the boat dip her nose in a very uncomfortable fashion, and causing the waves to wash the upper part from stem to stern. In plunging, the *Aigrette* did well, but neither boat had much advantage over the other. The conclusion arrived at was that the submersible alone possesses the right qualities, though the commission thinks that no sufficient reason for the submarine being abandoned. The submersible is the offensive boat, while the submarine is for coast defense. The experiments proved that the *Z*, which is of the Lutin type enlarged, both designed by the same constructor, has not gained superior qualities by the increase in dimensions, while the *Aigrette*, which is an improved Narval, possesses considerable improvements owing to her larger size. The committee considers that the submersible of the future should have a displacement of 400 tons, while that of the submarine should not exceed 100 tons.—"Army and Navy Register."

New Submarines.—The "Yacht's" Cherbourg correspondent states that orders have been received to put in hand two submarines to be known as *Q59* and *Q60*. They are large boats

of the *Emeraude* type modified, and are to displace 425 tons, with a length of about 180 feet. The engines are to be of 1,200 horsepower, and the speed will be 12 knots. These boats, although spoken of as submarines, are in reality submersibles, and will, it is hoped, be capable of acting at long distance from the coasts. Sixteen submersible boats are to be apportioned for construction between Cherbourg, Rochefort and Toulon, and at the latter port is to be built a very small submarine known as *Q61*, which is to displace no more than about 21 tons. This will be an experimental boat of a class capable of being carried on board battleships or large cruisers. The correspondent says that success is much desired, but that no one is blind to the difficulties which are presented in the construction and employment of a submarine capable of being launched at sea. The operation might be conducted without much difficulty in sheltered waters, but in rough seas would probably be impossible. In any case considerable interest attends the construction of the small boat.—"Army and Navy Register."

Destroyers M40 to M43.—The new destroyers, *M40* to *M43*, are to have a displacement of 336 tons, with a length of 190.29 feet, a beam of 19 feet 9 inches, and a draught of 9 feet 6 inches; the engines are to develop 6,800 I.H.P., to give a speed of 28 knots. The coal supply will be 30 tons, giving a radius of action of 2,300 miles. The armament will consist of one 6-pounder Q.F. and six 3-pounder Q.F. guns, with two torpedo tubes for 17.7-inch torpedoes.

Sully—*Stranding of.*—The first-class armored cruiser *Sully*, a vessel of 10,000 tons displacement and speed of 21 knots, struck on a rock in Along Bay, in the Gulf of Tonquin, on February 6, while going out for target practice.

Efforts have been made to save her, but so far these have been unsuccessful, and it is now thought that she will be a total loss.

GERMANY.

Navy Estimates.—The total of the German Navy estimates for 1905 is M. 22,900,200. This includes a vote for construction which is subdivided to allow for the completion of the battle-

ships *Hessen* and *Preussen*, the armored cruiser *York* and the small cruisers *Munchen* and *Lubeck*, and for the commencement of the two battleships *Q* and *R*, of the *Deutschland* class, the armored cruiser *D*, the small cruisers *O*, *Ersatz Wacht* and *Ersatz Blitz*, and two gunboats. There is a charge of a million and a half marks for submarines to be purchased. The total number of men voted was 36,622.

New Battleships.—The two new battleships *Hessen* and *Preussen* of the *Braunschweig* class are ready to begin their trials, and will probably be commissioned in the autumn of this year, and the *Brandenburg*, of an old type, has been reconstructed and entered into service again.

The small cruiser *Munchen* on her trials has made a speed of 22 knots with 10,580 H.P.

Several more vessels are expected to take the water from the German yards this year, although a large number were got off the stocks in 1904. The principal vessels will be the battleships *O* (building at Stettin) and *P* (building at Wilhelmshaven), the armored cruiser *C* (building at Bremen), and three protected cruisers, the *N*, *Ersatz Alexandrine* and *Ersatz Meteor*. These last-named vessels are building at the Weser Yard, at Kiel, and at Dantzic, respectively.—"Page's Weekly."

Ruebeck.—The German Admiralty has accepted the new turbine-propelled cruiser *Ruebeck*. The contract for this vessel called for 22 knots, but the *Ruebeck* made 23 knots an hour on her trial trip of 180 miles from Kiel to Swinemuende.

Cruisers.—The displacement of a cruiser, at present officially known as *C*, which was laid down in the course of last summer, will be 2,000 tons more than that of the *York*. The engines will work up to 26,000 horsepower, and the ship is to attain a maximum speed of 22½ knots. Another cruiser, officially known as *D*, is to be very similar to *C*. The turbine torpedo boat *No. 125* has made a trial trip of forty-two hours. The average speed attained was 28½ knots.

Three small cruisers, replacing the *Meteor*, the *Alexandrina* and the *U*, which, in the course of the present financial year,

have been laid down in the Imperial shipyards at Kiel and Dantzic and the yards of the Weser Company, are of the same type as the small cruisers *Bremen*, *München* and *Hamburg*, already completed. The *U* is to be finished by the spring of 1906, and the *Meteor* and the *Alexandrina* by the spring of 1907. Three other small cruisers—the *O*, the *Wachl* and the *Blitz*—have been projected. They are of the *Meteor* type and are to be 366 feet long by 44½ feet beam. They are to have a displacement of 3,400 tons each.—"Engineering," London.

ITALY.

Regina Margherita—*Trial.*—The trials of the *Regina Margherita* have been completed with fairly satisfactory results. On her first trial, at 14,000 H.P., she attained a speed of 19.3 knots, and later, with 20,600 H.P., the speed was 20.2 knots. It will be noted that for an increase in power of nearly 50 per cent. the increase in speed was slightly less than one knot, and this is a matter the Italian authorities might well give attention to. With some of our County cruisers a rather similar experience occurred, and it was not until the propellers had received attention that the vessels were able to give such excellent performances as they are now capable of. The *Regina Margherita's* boilers are of the Niclausse type.—"Page's Weekly.

New Ships.—Particulars of the design of the new armored cruiser *A*, which is to be built at Castellamare, have been published and show that this vessel will be in length 425¾ feet; beam, 68¼ feet; draught, 23¼ feet. The maximum thickness of the belt will be 8 inches, while the guns carried will be four 10-inch in pairs in turrets fore and aft, eight 8-inch in pairs in turrets on the broadside, sixteen 3-inch and eight machine guns. The engines will develop 18,000 horsepower, giving a speed of 22.5 knots, and the coal carried will be from 700 to 1,500 tons. Her displacement will be 10,000 tons, and the cost is estimated at £880,000.

A sister cruiser will be built at the same time and at the same yard. The first cruiser will probably be named the *San Georgio*,

but the second is known at present as *B* only. The names of the torpedo boats building for the Italian Navy are as follows: At Schichau, the *Sirio*, *Sagittario*, *Spica*, *Scorpione*, *Serpente* and *Saffo*. At Odero, the *Orione*, *Orsa*, *Olimpia*, *Orfeo*, *Alcione*, *Ardea*, *Albatross*, *Aibone*, *Astore* and *Arpia*. At Pattison's yard, *Pegaso*, *Perseo*, *Procione*, *Pallade*, *Cigno*, *Cassiopea*, *Calilope*, *Clio*, *Centauro* and *Canopo*. At Spezia, the *Gabbiano*.—"Page's Weekly."

JAPAN.

Kashima—*Launch of.*—Sir W. G. Armstrong, Whitworth & Co., launched from their Elswick works on March 22d the third battleship and the tenth war vessel built there for the Imperial Japanese Navy. This latest vessel is named the *Kashima*, and is one of two ordered at the beginning of last year by the Japanese Government; the other is being built by Messrs. Vickers Sons & Maxim, Limited, at the Naval Construction Works, Barrow-in-Furness. The *Kashima* is the most powerfully-armed vessel yet constructed in this country. She has four 12-inch guns, twin-mounted in barbettes, the upper part being of 9-inch plating, and the lower part, where protection is augmented by the ordinary citadel armor, of 5-inch armor. These 12-inch guns, which have hydraulically-operated mountings, are 46.7 calibers long, and weigh 59 tons. Firing 850 pound projectiles with modified Cordite explosive compound, it is anticipated that the penetrating power developed will be such as to cope at 3,000 yards range with any armor yet fitted to a battleship, and that the rapidity of fire will exceed two rounds per minute from each gun. There are also four 10-inch 34-ton guns of 46.76 calibers, placed singly in barbettes, built up of 6-inch plates, located at the four corners of the citadel. There are twelve 6-inch 8½-ton guns of 47 calibers. Five are mounted on each broadside inside the 6-inch citadel armor, and are separated from each other by 2-inch screen armor. The two remaining 6-inch guns are on the upper deck within 4-inch screen armor. There are also twelve 12-pounder guns, three 3-pounder guns, and six maxim guns.

In the design of the arrangements for serving the guns the lessons of the recent war have been utilized. There are five submerged torpedo tubes, firing 18-inch Whitehead torpedoes; two are forward and two aft, firing on the broadside, with one firing right astern. As regards the disposition of armor, the principle adopted is generally similar to that in the *Mikasa*, the most recently completed vessel for the Japanese Navy. The water-line belt is 9 inches in thickness for more than half the length of the ship, tapering to about 4 inches at the ram. This belt extends 5 feet below the water-line and 2 feet 6 inches above it. Surmounting it is a belt of armor, extending from the aft 12-inch barbette to the stem, and 6 inches in thickness. Immediately above this is the 6-inch citadel armor, reaching to the upper deck and inclosing also the two 12-inch barbettes. It is within this that the 6-inch guns are placed, while above this, again, is 4-inch screen armor for the two upper-deck 6-inch guns. The conning tower is of 9-inch armor, and there is an additional observation tower of 5-inch armor, while two more officers' shelters of 3-inch armor are provided on the boat deck amidships. In this way the fighting officers of the ship will have very advantageous positions, protected against the fire of the enemy's small guns.

The protected deck is 2 inches on the flat portions amidships and 3 inches on the sloping sides, where it joins the bottom of the main armor 5 feet below the load line. At the extremities, where the side armor is reduced in thickness, this deck is made 2½ inches thick over all. Further protection is given to the upper structure of the ship by thick protective plating on the top of the screen armor at the level of the boat deck. The length of the *Kashima* is 455 feet; the breadth, 78 feet 2 inches, and the moulded depth 43 feet 6 inches. With a normal draught of 26 feet 7½ inches the displacement will be 16,400 tons; the coal supply then will be 750 tons, but capacity is provided for 2,150 tons. Triple-expansion machinery and twenty Niclausse boilers are being constructed by Messrs. Humphrys, Tennant & Co., London. The designed

power is 16,500 horsepower, which, it is anticipated, will give the vessel a speed of 18½ knots.—"Engineering."

Kiji—*Launch of.*—The torpedo-boat destroyer *Kiji*, 200 tons, was launched at Kure, Japan, April 19.

MISCELLANEOUS.

Yarrow-Napier Motor Boat.—On March 4th an exhibition trial was made on the Thames, at Greenwich, of a little boat which is said—no doubt accurately—to have a speed considerably in excess of that of any other vessel of equal length. The next fastest boat in the world, of this class, is the American *Challenger*, the mean speed of which is stated by the United States press to be 25.01 knots. Next to this is the *Trêfle-à-Quatre*, a French boat, which has accomplished a speed of 22.7 knots. The Yarrow-Napier motor boat is 40 feet long, and is fitted with two four-cylinder petrol engines, driving twin-screws, and giving collectively about 120 horsepower. The boat has been constructed by Messrs. Yarrow & Co., and the engines by Messrs. Napier & Co. She is, we believe, intended to be used by Mr. S. F. Edge for racing purposes, as she is to be dispatched to Nice, where she will doubtless take part in the forthcoming competitions in the Mediterranean.

A trial of this little vessel had been previously made on the measured mile in Long Reach, when a speed of practically 26 knots was reached. The run against tide was made in 2 minutes 25 seconds, and the mile with tide was covered in 2 minutes 12.6 seconds. The mean speed was therefore 25.988 knots, or just on 30 statute miles an hour. The result is more remarkable as the day was by no means favorable to a good performance, for there was, according to the meteorological reports, half a gale of wind blowing at the time, and even in the inclosed waters of Long Reach this would make a considerable difference to the speed result for so small a vessel. In reference to the fraction of a second recorded, it may be stated that the time was taken by the official timekeeper of the Automobile Club, Mr. Swindley, who, of course, is accustomed to deal with decimal parts of seconds, and was

confirmed independently by Mr. Marriner, of Messrs. Yarrow's staff, who is also an expert in taking time records.

The hull is constructed of what is described as a special steel, which is probably of the description used by Messrs. Yarrow in their torpedo craft and has had so much effect in lightening the structure. The framing is on the longitudinal principle in order to secure the maximum strength fore and aft. Naturally, the scantling of the hull in a petrol motor boat may be much lighter than in a steam-driven vessel, as there is no boiler to add to the displacement, and the weight of fuel is considerably less—about one-third that of coal.

As already stated, the length of the boat is 40 feet, the width is 5 feet, and the draught of water of the hull is 8 inches. The total weight of the boat in running trim is 3 tons and 4 hundredweight, of which the machinery weighs approximately one-half and the hull the other half. The engines have each four cylinders, or eight in all, the dimensions being $6\frac{1}{2}$ inches for the diameter and 6 inches for the stroke. Each set of engines drives a three-blade propeller.

The form of hull is unusual, the shape having been arrived at by means of a long series of experiments made by Messrs. Yarrow with full-sized models towed by a torpedo vessel. The bottom for the greater part of the length is quite flat, the bilge being only just rounded off. The bow is by no means sharp, and there is no gripe forward, the forefoot being quite blunt; but this is of little consequence once high speed is reached, as the bow lifts right out of the water for a considerable distance, the vessel running entirely on the flat part of the bottom. This is a condition purposely secured, the idea being to make the boat rise bodily in the water when traveling at high speed. In the early days of torpedo-boat construction it was noticed that the displacement was reduced somewhat when the highest speed was reached; but, naturally, with the greater weight of steam machinery this effect was hardly a practical factor, excepting at a great expenditure of power. Many of our readers also will doubtless call to mind the suggestions made about thirty years ago by a clergyman, the Rev. C. Ramus. His con-

tention was, if we remember rightly, that the way to get the greatest speed possible from a vessel would be to make her of such a shape that she would offer excessive resistance to passage through the water, and therefore she would rise bodily out of the water when great power was exerted by the engines, so that the friction and wave-making features would be reduced. Mr. Ramus was a good deal laughed at at the time, but in view of Mr. Yarrow's experiments he appears, like so many other inventors, to have only been thinking thirty or forty years before his time; but although his principles may have been sound within limits, he was quite visionary in attempting, as we believe he did, to force them on the Admiralty for the construction of warships. It would have been pleasant, however, if the reverend inventor could have lived to see the really wonderful performance of the little boat in Greenwich Reach on Saturday last.

Amongst the models tried by Messrs. Yarrow—and they were, it must be remembered, the full size of the actual boat—the one which gave the least resistance at speeds aimed at was flat from end to end; in fact, no "shape," as the boat builder understands the term. The hull appeared to glide on the surface of the water, and the recording instruments indicated that such was approximately the case. This points to the fact, as Mr. Yarrow has stated, that the power exerted by the engines were better devoted to supporting the boat on the surface rather than by putting it through the water. With a flat-bottom boat the speed may be such that the water, which would be displaced were the boat at rest or traveling slowly, has not time to move downwards out of the way before the boat has passed, and as no two things can be in the same place at the same time, the boat has to rise bodily. That this will occur to some extent, even with ordinary ship-shape vessels, when the speed is excessive, is well known, and, with a flat-bottom craft, where the movement of the water must be at first vertical, the action will evidently be intensified. This was well illustrated by Mr. Yarrow by means of the analogy of a flat stone being thrown on the water, making what children

style "a duck and a drake." Evidently the stone would travel further and faster than if the same energy were expended in projecting it partially submerged. Considering the speed at which the boat traveled—or, perhaps, for reasons stated, it was on account of the speed—the waves thrown off appeared very small, although those that were thrown off were steeper than usual. It was difficult to judge, on account of the disturbed state of the river, and it would be interesting to see the boat tried on a perfectly calm day. If runs could be made at the best speed in deep water, and also in water so shallow as only to give a sufficient margin of draught just to float the vessel, some interesting results might be obtained. Possibly a safe stretch, with a soft bottom, might be found in the estuary of the Thames or Medway.

In this boat, as stated, a considerable length of the forward part is clear of the water when she is traveling at her best speed. Unfortunately, there was too much popple on Saturday to estimate the distance, but evidently it was something considerable. It would naturally add to the speed in quite smooth water if the forward out-of-water length were sawn clean off, as the weight would be reduced; but that would give a very bad bow for waves to strike against, and it is possible the initial resistance might be too great. It may be suggested, however, that a cone-shaped bow might be of advantage, as it would be lighter, and oppose less projected surface to the blow of the waves than even the orthodox section.

The performance of this boat is exceedingly interesting, as it gives information regarding what takes place at extremely high speed in a vessel propelled by its own screw or screws. It is not difficult to arrive at conclusions in this field of research by means of tank experiments, leaving the disturbing action of the screw out of account; but that does not represent the actual condition of affairs in a ship at sea, when the propeller must have considerable influence on the stream lines. To arrive at some conclusions in this respect by tank experiments, a model has had a screw placed in the usual position

and driven by an outside means, but to have recourse to such a plan obviously is attended with considerable difficulty.

Mr. Yarrow has attacked this problem with his usual thoroughness and appreciation of the practical needs of the situation, and has added one more to the long list of benefits he has conferred on the science of marine propulsion. He states that had a boat of similar dimensions to that exhibited on Saturday been required to be driven by steam, his firm would not have been prepared to promise more than 16 knots as a maximum; so it would appear that the substitution of the petrol engine for a steam engine and boiler has resulted in a gain of no less than 10 knots.

Mr. Yarrow estimates, on the basis of the performance of the present boat, that a destroyer of 220 feet with petrol engines would attain a speed of 45 knots. The destroyers of this length built by Messrs. Yarrow for the Japanese Government steamed at 31 to 32 knots. As Mr. Yarrow remarked, all that remains to be done in order to reach the 45 knots is to perfect the internal-combustion engine, so as to enable larger sizes to be used successfully.

Such advances are without precedent in the history of marine propulsion; and they hold out such rewards that it can hardly be doubted every effort will be made to adopt the internal-combustion engine for still larger vessels. The difficulties in the way are numerous, the most prominent one at present being the high price of the fuel used; but beyond this there are many physical and mechanical troubles to be overcome before internal-combustion engines of large size can be used at sea.

The saving in weight of fuel is, of course, considerable, it being placed by Mr. Yarrow at two-thirds that of coal for ordinary steam machinery of the same power. The addition this would give to the radius of action is a military advantage, the value of which is apparent for torpedo craft; whilst it would render destroyers far more capable of accompanying a fleet, as, for a given distance to be covered, they need not be weighted down to the same extent, and would be more sea-

worthy. In the boat tried on Saturday there is a petrol tank of a capacity of 100 gallons—a quantity sufficient to take the boat 130 miles at full speed, or double that distance at three-quarter speed.—" Engineering," London.

Roosevelt.—The vessel which Civil Engineer R. E. Peary, U. S. Navy, will use in his attempt to reach the North Pole has been launched, as has already been announced in these columns, and is well on the way toward completion. The designs were made by William E. Winant, of the Bureau of Construction and Repair in the Navy Department. All the details of the vessel take into consideration that peculiar work upon which he will be engaged. The dimensions of the *Roosevelt*, as the vessel has been named, are as follows: Length on load-water line (between perpendiculars), 161 feet; length on deck (about), 172 feet; length over all, from tip to tip of rail (about), 182 feet; breadth, molded (to outside of plank at deck beam), 33 feet; breadth (to outside of plank at L. W. L.), 32 feet; breadth, extreme, over guard, 34 feet 2 inches; depth, molded (from top of main-deck beam at side to bottom of keel at midship frame), 20 feet; draught, forward, 15 feet 3 inches; draught, aft, 16 feet 9 inches; mean draught, amidships, 16 feet. Her displacement, when ready for sea, with all coal and stores aboard, will be about 1,500 tons.

Probably in no part of the world can be found a model or form of hull similar to this vessel, whose mission is to drive into, break down and force away the ice fields in front, with a stern so shaped that the overhanging portions will more or less protect the screw when the heavy ice floes come together against the vessel's quarters. There is no "tumble-home" of the top sides such as may be found in former Arctic vessels, but instead the top sides "flare out" up to the rail, which admits of working a heavy "guard strake."

The purpose of this guard strake, apart from being a buffer, is to help to lift the vessel out of the water as the ice crushes about her. As can be seen, the ice will press against her sides, and then, as they offer first resistance, it will rise and catch under the counter or overhang of this guard and bodily raise

the vessel. In case the ship, on the other hand, has been frozen in a thick pack of ice, and it is desirable to free her, hydraulic jacks are set upon the ice and brought to bear upon the under side of the guard, and these, in turn, will raise the craft, and as she is permitted to settle back her own weight and her form, acting as a big wedge, will tend to break away clear. This is a peculiarly novel arrangement.

Reference to the midship section and the lines will show the combination in form of the old-time "frigate floor" and the modern ferryboat bilge, which, together, gives a body that will admit of the vessel laying over on her side without damage, and also gives what is known in ship parlance as "freezing section," from lateral compression of ice from without.

The most important feature of this vessel's form is the bow and fore-foot. This is designed so that when driving into thick ice the vessel will ride upon the ice and break it down and at the same time keep the broken ice from piling so high as to be an impediment to the next ramming. The extreme flare of the bows from the water line to the forecastle deck is for this purpose also.

The *Roosevelt* is braced, girded and reinforced as never was craft before; she will be able to withstand enormous pressures from surrounding fields of ice. This "squeeze" of the ice will tend to lift rather than crush her between the grasp of the gathering pack. The extreme "ferryboat" form of midship section will raise her up out of the ice the harder the squeezing becomes.

The vessel may be technically described as a "three-masted, fore-and-aft, schooner-rigged steam vessel, with auxiliary sail power," larger than Nelson's famous *Fram*, but about the size of the Antarctic ship *Discovery*. There the similarity ceases.

Continuity of strength, fore and aft, laterally and vertically, only have been considered in view of the work to be accomplished, as may be noted from the midship section and inboard profile. When it is considered that the bow framing extends ten feet aft of the stem and is of solid dead wood, etc., some idea of the terrible pounding this vessel will stand can

be appreciated. This solid framing is from the natural white oak crooks and is bolted from all directions. In addition to this heavy framing a three-quarter-inch vertical apron plate is worked inside of all to prevent the forward hood ends of the double planking from "starting" during the continual ramming into the ice. The archives of shipbuilding fail to show a vessel so strongly framed as the *Roosevelt.*

Compared with the United States Government revenue cutters *Bear* and *Alert* and with Arctic whalers of recent years, the *Roosevelt* is a much stronger vessel throughout. She is double-framed and double-planked with two courses of 5-inch oak plank and ceiled on the inside of the frame with 3-inch yellow-pine ceiling. In addition to this heavy framing, big 14 x 22 inches "'tween"-deck beams are worked in every frame at the water line to prevent lateral crushing of the vessel.

Between the main deck and the "'tween"-deck beams heavy athwartship diagonal braces are worked to prevent the vessel being crushed from the bilges upward.

The longitudinal strength is maintained in each side by very heavy oak and yellow-pine keelsons, clamps, stringers, deck plank and inside and outside planking, all of which is copper bolted in all directions.

To take up any vertical working of the vessel that may occur from months and months of forging into and breaking down the ice, heavy wrought-iron tie rods are fitted from the lower side of the main keel to the top of the deck beams. These tie rods are run through wrought-iron pipes (which act as beam stanchions), and they may be "set up" at will on the main deck.

To take the rub and grind of the floating ice, the bow, sides along the water line and the stern are protected by steel plating. At the stem this plating, an inch thick, reaches from the keel all the way up to about 6 feet above the load-water line and extends aft from the stem for quite 12 feet. This is for protection of the bow when ramming. The water-line plating, which is $\frac{3}{8}$ of an inch thick, is a continuous belt 5

feet wide, 1 foot only above water, the 4 others being below, where they will be more serviceable. The fact that this steel plating should have to reinforce the unusually heavy double course of planking is significant of the tremendous wear and tear to which a craft is subjected in the polar seas.—"Army and Navy Register."

Ferry Launch for Navy Yard, Portsmouth, N. H.—Plans have been made for a ferry launch to be used at the Portsmouth, N. H., Navy Yard. The dimensions of this boat will be—

Length over all, feet	80
on load-water line, feet and inches	70- 9
Beam, outside of planking amidship, feet	20
Draught, feet and inches	5-11½
Displacement, tons	80

A 300-horsepower gasoline engine will be installed to propel this boat. The engine will have six cylinders of 12 inches diameter by 14 inches stroke and will weigh 8,800 pounds. The total weight of machinery, including tanks, will be about 12,025 pounds. The gasoline tanks will hold a supply of 500 gallons. A small hot-water heater with radiators in cabins and pilot house will furnish heat during the winter months.

MERCHANT SHIPS.

Amerika—*Launch of.*—On Thursday, April 20th, Messrs. Harland & Wolff, Belfast, launched the large steel twin-screw passenger steamer *Amerika* for the Hamburg-American Line. The new steamer has a gross tonnage of about 22,800 tons, and, when completed, will be the largest vessel afloat outside the British mercantile marine. She will be fitted for a large number of first, second, intermediate and third-class passengers. Several new features have been introduced, the chief of which are the special restaurant and a fine recreation room containing a gymnasium and other facilities for athletic exercise. The machinery is of the builders' quadruple-expansion balanced type, reducing vibration to a minimum.

La Provence.—On the 21st of March the latest flyer of the French line was successfully launched near St. Nazaire, in the presence of the Ministers of Commerce and Public Works and the First Secretary of Marine. The *Provence* is of a considerably larger size than the ships of the French line at present in service, and, indeed, is the largest ship of the French mercantile marine, and the largest ship ever built in France.

She has a length of 626 feet, with beam of 69 feet, and displaces, at a draught of 26 feet, 19,200 tons. She is fitted with two engines, operating twin screws, and developing a total of 30,000 indicated horsepower, with which it is expected that a speed of 23 knots will be maintained. The draft has been limited because of the fact that the harbor of Havre, which is the eastern terminus of the trip of the French liners, is relatively shallow, and will not admit of the draught given the English ships entering the port of New York. The ship was commenced in December, 1903, and is expected to be ready for service early in 1906. It was proposed, when the plans were being considered, to fit her with turbine engines, but the Companie Generale Transatlantique had scarcely the courage to initiate this system in a steamer of such importance. Her

crew numbers 439 all told, and she has provision for 1,900 passengers.—"Marine Engineering."

Dieppe.—The London, Brighton and South Coast Railway Company's new turbine steamer *Dieppe* was launched on Thursday, April 6th, by the Fairfield Shipbuilding and Engineering Company, Limited, Govan. The vessel is very similar in general dimensions to the same company's *Brighton* (see "Engineering," vol. lxxvi, page 325), which was launched by Messrs. William Denny & Bros., Dumbarton, in June, 1903; but on the later vessel a considerable number of improvements have been made. The beam has been increased, and the after portion of the ship, which is open in the *Brighton*, has been closed in, thus giving greater comfort and protection to the second-class passengers and insuring still further the safety of the steamer. The *Dieppe* is 274 feet in length, 34 feet 8 inches in breadth and 14 feet 6 inches in depth. The first-class dining saloon, extending right across the ship, gives dining accommodation for 62 passengers, and there is sleeping accommodation for 36. The second-class sleeping saloons are on the lower deck, and accommodate nearly 200 passengers. The propelling machinery consists of three independent Parsons compound steam turbines and two condensers. Each of the three turbines drives a separate shaft, with one three-bladed propeller on each shaft. In order to cope with the exigencies of the service, the builders have designed a special starting, reversing and maneuvering gear, which is quick in its action, while the movements of all the turbines can be controlled from the starting platform by one engineer. The boilers are four in number, single-ended, of the ordinary multitubular marine type, and fitted with Howden's forced draft. They are constructed entirely of steel, and adapted for a working pressure of 150 pounds per square inch. The turbines and other machinery have been constructed by the Fairfield Company.—"Engineering," London.

James C. Wallace—*Launch of.*—While the *Wallace* is 8 feet shorter than the steamer *Augustus B. Wolvin*, the largest vessel on the lakes, the cubical capacity of her cargo hold is actually greater because it is four feet wider at the top and

five feet wider at the bottom, while only being one foot less in length. The *Wallace* has thirty-two hatches as against thirty-three in the *Wolvin*. In all other respects the steamers are structurally duplicates. The *Wallace* is 552 feet over all, 532 feet keel, 56 feet beam and 31 feet deep. The hopper extends in one continuous length of 408 feet without bulkheads or divisions of any kind, and in width it measures at the top 47 feet, and at the bottom 29 feet. The space between the sides of the ship and the sides of the hopper is used for water ballast, so that the water ballast, as well as being in the usual double bottom underneath the hopper, extends up the sides to the height of the main-deck stringer. This construction was adopted to accommodate the use of automatic clam shells in unloading the cargo, and while it serves this purpose, it also serves to make a stronger vessel. Another feature of the construction is the fact of the ordinary hold stanchions being dispensed with, and in their place a system of girder arches is substituted to support the upper deck as well as the sides of the vessel. There are thirty-two cargo hatchways on the spar deck, each one measuring 33 feet by 9 feet in the clear, and spaced 13 feet apart centers, so that it will be possible for the clam shells to unload the vessel entirely without any hand shoveling. These hatchways are fitted with a patented system of steel-plate sliding-hatch covers known as the Brousseau device, operated by steam engines and shafting, so that no manual labor is required for the opening and closing of the hatch covers.

The spar deck is continuous and flush from stem to stern, and the only erections on it are the pilot house and texas forward, and the coamings around the engine and boiler openings and dining-room skylight aft. The water-ballast space is divided into numerous compartments by watertight athwartship bulkheads fitted at intervals of about 60 feet, and the total ballast capacity is about 8,000 tons of water. On the spar deck are six 8 by 10-inch single-drum engines, carrying each a steel-wire mooring line for the usual mooring and warping purposes. In fact, steam has been used wherever possible to displace manual labor. There is a steam windlass fitted

for handling the two 8,000-pound anchors, and a steam capstan on the spar deck aft. She will be fully equipped with electric lights throughout, and has duplicate plants, so that there will always be one to fall back on in case of the other giving out. In the forward end of the vessel, immediately under the pilot house and texas, there are five staterooms for owners and their families, also accommodations for their private galley, dining room and social parlor; also two toilet rooms. They are entirely set apart from the crew's quarters and will be luxuriously furnished and fitted out. The ship's officers are accommodated on the deck immediately below the owner's quarters, and the engine-room officers are quartered alongside of the engine at the after end of the vessel, where is also located the kitchen, dining room and mess room for the crew.

The propelling machinery, as is usual in lake vessels, is located in the extreme after end of the boat. The main engine is of the quadruple four-crank type, with cylinders 18½ inches, 28½ inches, 43½ inches and 66 inches diameter, each having 42 inches stroke of pistons, and they are designed for an indicated horsepower of 2,000 when making 80 revolutions per minute. The cylinders are arranged from forward in the following order: High-pressure, first-intermediate, second-intermediate and low-pressure. The high-pressure is fitted with a liner secured in the usual way. The valves of the high, first and second intermediate are of the piston type, placed in front of their respective cylinders, and driven by "Joy" radial valve gear. The low-pressure cylinder is fitted with a double-ported slide valve on the after end, operated by double-bar Stephenson link motion. The bedplate is of the girder type, of box section, in two pieces, bolted together, and has five main bearings lined with white metal. There are four back and five front columns, the former acting as guides for the crossheads. The piston rods are of steel 5⅜ inches diameter, and the connecting rods of hammered iron 9 feet long between centers, with wedge adjustment at top and "T" ends with bolts at bottom. The crossheads are of cast steel, keyed to piston rods and fitted with steel crosshead pins, secured with double taper and nut. The slippers are of bronze of large

surface and easily adjustable. The crank shaft which, with its four cranks is built without couplings, is 12½ inches diameter. The crank pins are each 12½ inches diameter by 13½ inches long. The thrust is of the "horseshoe" type with six go-ahead collars and five backing. The engine is fitted with a direct-acting steam, and a hand, worm reversing gear, also a steam turning gear at aft end of thrust shaft. The propeller is four-bladed cast steel, of sectional type 14 feet 6 inches diameter and 14 feet 6 inches pitch. The outboard bearing is 13 inches diameter by 4 feet 8 inches long, filled with lignum vitae.

The boilers, two in number, are of the Babcock & Wilcox type, and placed with a 12-foot space between them to fire athwartship. The working pressure is 250 pounds per square inch, and the steam is superheated, the superheater being placed on top of boilers proper. The boilers are fitted with the mechanical stokers built by the Duluth Stoker Co., the coal being fed into the hoppers, passing from thence on to traveling grates, the ashes being deposited at the back of boilers and discharged overboard by means of steam-driven elevators. The boilers are fitted with a system of induced draft, having two 7-foot 6-inch diameter fans driven by double 6 by 5-inch high-speed engines. To purify and heat the feed water before reaching the boilers, two Learmonth purifiers are fitted, also a large heater into which all the auxiliaries exhaust. There are the following auxiliaries in the engine room, the pumps, all being of the Blake type: One vertical cross-compound simplex air pump; two horizontal cross-compound simplex ballast pumps; one horizontal compound duplex feed pump; one horizontal duplex pony pump; one horizontal duplex bilge pump; one horizontal duplex cooler pump; two general electric generating sets of 15-kw. for electric lighting; one Globe steam steerer and one Sturtevant fan with attached engine for ventilating purposes.

The coal bunker is fitted in front of the boiler room and has capacity for about 350 tons of coal. In every respect the vessel has been fitted out and built to meet the most modern requirements of lake service.—"Extract from Marine Review."

YACHTS.

New Turbine Yacht for the King.—The order for a new yacht for the King has been placed with Messrs. A. and J. Inglis, Pointhouse, Glasgow, who have a very high reputation for the design and construction of such craft. It will be the first Royal yacht constructed by a private firm within recent years. The Admiralty adopted the very wise course of giving the firms invited to submit designs a completely free hand, and the designs carried only a *nom-de-plume*. The committee which was subsequently appointed to adjudicate upon the design included the Commodore of the Royal Yachts, Sir A. Berkeley-Milne, the Director of Naval Construction, Mr. Philip Watts, and Admiral Sir John Fullerton, who was for long the Commodore of the Royal Yachts. They had no knowledge as to the origin of any of the designs. This committee, we understand, were unanimous in their preference for the Inglis design, and when their report was submitted to the King, he also, after careful examination of the general arrangements, acquiesced in the decision.

The new yacht is primarily intended for short cruises and for visits to harbors where the draught of water is limited, as in the case of Flushing, Nice and some other Continental ports. The size of the ship has therefore been limited, although a cruising speed of 17 knots is expected, with a go-astern speed of 15 knots. The vessel will be 285 feet long on the load-water line, 40 feet in breadth, and of 2,000 tons gross. The dining room, the Queen's drawing room and the smoke room will be on the upper deck aft; and it is interesting to note that the decorative work, furniture, &c., will, as far as possible, be made at Glasgow, showing that this city has advanced very considerably in artistic production. The propelling turbines will be of the Parsons type, and in accord-

ance with the now almost universal arrangement there will be three shafts—the high-pressure turbine being in the center, and the low-pressure turbine for going ahead on the side shafts, and abaft of them the go-astern turbines. Cylindrical boilers are to be adopted for generating steam.—"Engineering."

Albion.—The triple-screw turbine yacht *Albion*, which has been a feature of such interest on the Tyne for some time past, sailed on Thursday night and arrived early on Saturday morning at Southampton. The yacht has been built by Messrs. Swan, Hunter & Wigham Richardson, Limited, for Sir George Newnes, Bart, M. P., and is from the design of Sir W. H. White, K. C. B. The machinery consists of turbines by the Parsons Marine Steam Turbine Company, driving three propellers. Before the vessel left the river she went through a long series of exhaustive trials, from which were gathered data which will prove of great value in the application of turbines to similar vessels.—"Page's Weekly."

On Thursday, April 20th, Messrs. Ramage & Ferguson, Limited, Leith, launched a twin-screw steam yacht of over 1,000 tons, Thames measurement, for Baron De Forest. The vessel is constructed on the double-deck principle, so popular with some yachtsmen nowadays, the shade deck being continuous right fore-and-aft, and the sides built up, except for a part aft of the forecastle and another part aft in way of the gangways. The accommodation is, perhaps, the largest ever attempted in a yacht of this tonnage. The dimensions are: 260 feet long over all, and 213 feet on the water line, 31 feet beam and 16 feet deep. She will be rigged as a pole-masted schooner. Immediately forward of the machinery space on the cabin deck is a large stateroom, etc., for the owner, with a stairway leading to the main deck, communicating with a private boudoir and a large dressing room. Just aft of these rooms on the main deck is a spacious dining room, and on the starboard side of the boiler casing there is a library and an anteroom, etc., through which the dining room is entered. On the port side of casings are servants' rooms, larder, etc., and in the

casings themselves are the pantry and galley. Aft of the engine casing on the main deck is a large deck house, forming a drawing room, with a vestibule leading to the cabin deck. In the poop are three good staterooms, bathroom, etc., and on the cabin deck aft of the machinery space are large staterooms, with bathrooms, servants' rooms, etc. On the shade-deck forward is a large deck house, containing a sitting room, chart room and captain's room, with navigating bridge above. Aft on the shade deck there is also a deck house, forming another sitting room.

The yacht is not intended to be a speedy craft, but will cruise at a speed of 13 knots. She will be propelled by twin-screws driven by two sets of triple-expansion machinery, embodying all the modern improvements, and capable of indicating 1,400 horsepower. There is one large single-ended main boiler, having a working pressure of 180 pounds, and a Blake donkey boiler for work in port. She will have a coal-carrying capacity of about 230 tons, which should enable her to cross the Atlantic without recoaling. The funnel is provided with a patent spark catcher. There will be a complete electric-light installation, Hall's ice machine and all up-to-date conveniences. This vessel is the last designed by the late Mr. G. L. Watson.—"Engineering," London.

OBITUARY.

ASSISTANT NAVAL CONSTRUCTOR JOSEPH E. McDONALD, U. S. NAVY.

Assistant Naval Constructor Joseph E. McDonald was born in Indianapolis, Indiana, on February 17, 1872. He was appointed a Naval Cadet on September 7, 1888, and was graduated from the U. S. Naval Academy in May, 1892.

While at the Academy Cadet McDonald proved himself to be possessed of unusual ability and naturally assumed a position of leadership amongst his companions. During his final year he held the highest cadet office in the battalion.

After graduation Cadet McDonald was ordered to the U. S. S. *Newark*, but was shortly afterwards sent to Paris, where he spent three years as a student of Naval Architecture.

On July 1, 1894, he was commissioned an Assistant Naval Constructor, and was first assigned to duty at the works of the Newport News Shipbuilding and Dry Dock Company, Newport News, Virginia. He afterwards served for several months on board the U. S. Ships *New York*, *Maine*, *Texas* and *Indiana*, and on June 3, 1897, returned to Newport News, where he reported for duty as the Assistant Superintending Naval Constructor. On October 26, 1898, he was transferred to Richmond, Virginia, in connection with the construction of several torpedo boats and destroyers, and in June of 1899 was ordered to the Navy Yard, Mare Island, California, where he remained until granted a sick leave of absence in January, 1902.

This leave of absence was extended from time to time in the hope that his health might finally be restored. In November of 1904 he was ordered to the Army General Hospital at Fort Bayard, N. M., for treatment, where he died on May 29, 1905.

The death of Assistant Naval Constructor McDonald is a loss not only to our Society, but to the Navy as a whole and one that will be felt by many in other walks of life.

BOOKS RECEIVED.

A CLASS-BOOK OF NAVAL ARCHITECTURE.—By W. J. LOVETT, Lecturer on Naval Architecture at the Belfast Municipal Technical Institute. New York and London: LONGMANS, GREEN & COMPANY. Price, $2.50.

This book is intended primarily for use in the class room, for which purpose it is well adapted. It will also be found of much value for reference by the professional man as well as the student.

Beginning with a chapter on mathematics, the various subjects relating to ship construction are treated in detail in a brief but clear manner. The work will undoubtedly be in much demand in the various technical schools.

STIRLING.—A book on Steam for Engineers, edited by the engineering staff of the Stirling Company.

This volume contains much valuable information with regard to boilers, arranged in convenient form.

The Stirling boiler is described in detail and a large amount of data given concerning this type. The treatise is subdivided into subjects as follows:

The Stirling Water-Tube Safety Boiler, Water-Tube *vs.* Fire-Tube Boilers, Works of the Stirling Company, Heat, Air, Water, Impurities in Boiler Feed Water, Steam, Moisture in Steam, Flow of Steam through Pipes and Orifices, Superheated Steam and the Stirling Superheater, Combustion, Fuels for Steam Boilers, Determination of Heating Values of Fuels, Fuel Burning, The Stirling Chain Grate Stoker, Utilization of Waste Heat, Chimneys and Draft, Analysis of Flue Gases, Steam Boiler Efficiency, Horsepower Rating of Boilers, Rules for Conducting Boiler Trials, Tables of Tests on Stirling Boilers, Boilers for Mining Service, Principles of Steam Piping, Boiler and Steam-Pipe Coverings, Boiler Cleaning, Care and Management of the Stirling Boiler, Specifications for Masonry in Stirling Boiler Settings.

ASSOCIATION NOTES.

PRIZE ESSAY.

At a meeting of the Council held on Saturday, March 11, 1905, at the Navy Department, the votes of the members for the prize essay were opened and counted.

As a result of this count, the gold medal and prize of the Society for the most important contribution to the JOURNAL during the year 1904 was awarded to Ernest N. Janson, M. E., for his article entitled "Steam Turbines, with a Special Reference to their Adaptability to the Propulsion of Ships," which appeared in No. 1, Vol. XVI.

ERRATA.

No. 2, Vol. XVII.

Page 394, 10th line from bottom, change "650 tons" to read "1,650 tons."

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